Note to requester: Attachment is immediately following.

From: Audrain, Margaret
Sent: Thu, 30 Aug 2018 18:21:46 +0000
To: Tregoning, Robert
Cc: Hiser, Matthew;Purtscher, Patrick
Subject: JNRA Meeting Sept 2018 Harvesting.pptx
Attachments: JNRA Meeting Sept 2018 Harvesting.pptx

Rob,

Please see attached for the harvesting presentation. I added the harvesting needs slides, as discussed. Feel free to make edits or let me know if you want something changed.

Thanks,

Meg

Harvesting of Aged Materials from Operating and Decommissioning Nuclear Power Plants

M. Audrain, M. Hiser, P. Purtscher, R. Tregoning

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

The views expressed in this presentation are those of the author, not necessarily those of the U.S. NRC.

Motivation

U.S.NRC
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- US utilities are interested in extending operating lifespans from to 60-80 years:
  - Key technical areas for aging management:
    - RPV embrittlement, irradiation-assisted degradation of internals, concrete structures and containment, electrical cables
- Many plant shutdowns worldwide provide opportunities to harvest components during decommissioning
  - Harvesting can provide valuable information on aging mechanisms to increase confidence in aging management
- Limited budgets make cooperation for new research, including harvesting, essential:
  - Important to align interested parties
  - Leverage resources for maximum benefit

NRC Harvesting Experience

U.S.NRC
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- NRC has participated in several programs:
  - RPV, CRDM penetrations, RCS piping, RPV internals, neutron absorbers, and cables
  - Materials harvested from unfinished, operating and decommissioning plants
  - US and international programs
- NRC experience is there is significant value in using harvested components to confirm data from other research programs

Lessons Learned

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

- Technical
  - Provides highly representative aged materials for research
  - Important to gain as much information as possible before committing to specific harvesting project

- Logistical
  - Expensive and time-consuming effort
  - Leveraging resources helps mitigate cost challenges
  - Transportation of irradiated materials is cumbersome and time-consuming

Current Work

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- Develop strategic approach to materials harvesting
  - Past efforts have been reactive to individual plants shutting down
- Prioritize data needs best addressed by harvesting, considering:
  - Applicability of harvested material for addressing gaps
  - Importance of harvested materials over laboratory aging
  - Fleet-wide vs plant-specific applicability of data
  - Regulatory considerations
  - Harvesting cost/complexity
- Database for Sources of Materials
  - Compilation of previously harvested materials available at US national labs as well as those available for future harvesting
  - NRC is interested in engaging with other organizations in developing the database

Needs - Metals

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- RPV
  - High fluence & high shift vessel with well-established unirradiated properties (or a means to estimate them)
    - Through thickness section to validate fluence & attenuation models
    - Measure fluence, toughness, & chemistry as a function of through-thickness position
  - Samples from virtually any vessel
    - Of sufficient size to enable measurement of both the Charpy transition curve and master curve transition temperature T_0
    - This testing
      - Enables demonstration of the conservatism of regulatory approaches for transition temperature prediction
      - Provides data supporting evolution from the use of correlative (Charpy-based) to direct measurement (fracture toughness-based) approaches

Needs - Metals

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- CASS and Internals
  - High fluence reactor internals
    - >50 dpa 304 SS from high core outlet temp plant
    - Bounding temperature and high fluence for void swelling
  - Thermally aged unirradiated CASS
    - >30 years at ~320° C; Validate accelerated aging data
  - Moderate fluence (1-2 dpa) CASS
    - Bolster technical basis for embrittlement in this fluence range
- Components with known flaws
  - Example: weld overlays over known flaws
    - NDE evaluations or to assess effectiveness of mitigation techniques
- Components with limiting fatigue life
  - Confirm fatigue calculations are accurate by inspecting for flaws

Needs - Electrical

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- Cables
  - Low and medium voltage cables
  - Cables protected with fire retardant coating
- Electrical components
  - 1E MOVs from harsh and mild environments
  - 1E Air operated valves; 4160 1E breakers
  - 1E Molded case breakers 480V, 250V DC, 125 VDC,
  - 1E Relays from mild environment GE – HFA, Agastat timing relays, any from Westinghouse, Potter Brumfield, Stuthers Dunn etc.,
  - Electrical penetrations; Batteries
- Fire research interest
  - Electrical enclosures
    - Distribution : switchgear, MCCs, LCs | Control : Horseshoe, SSCP, ASP, etc.

Needs - Concrete

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- Structures exposed to high radiation
- Post-tensioned structures
- Corrosion of reinforcing steel, tendon, liner, embedment
- Spent fuel pool and transfer canal-boric acid attack on concrete in PWRs
- Alkali Aggregate Reaction
- Large structural sections for testing

Conclusion

U.S.NRC
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- Harvesting can yield highly representative and valuable data on materials aging
- A focused approach to choosing harvested materials is necessary to get best outcomes
- NRC is working on a sources of materials database and prioritizing data needs based on relevant criteria to inform decisions on specific harvesting opportunities
- NRC welcomes opportunities for cooperation and leveraging with other interested research organizations

Discussion

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- Has the planned work on harvesting RPV materials and concrete from Hamaoka 1 been completed?
  - Can those results be shared with NRC?
- Does JNRA/CRIEPI have any other harvesting programs in progress or planned?
  - If so, any information that can be shared?
  - If still being planned, is there interest in additional partners?
- Would there be interest in participating if a harvesting project was identified in the US or another country?
  - Should we reach out to JNRA if other harvesting opportunities develop?

Note to requester: Attachment is immediately following.

From: Audrain, Margaret
Sent: Tue, 28 Aug 2018 17:54:03 +0000
To: Hiser, Matthew;Purtscher, Patrick
Subject: JNRA Meeting Sept 2018.pptx
Attachments: JNRA Meeting Sept 2018.pptx

Matt and Pat,

Please take a look at the attached presentation for Rob's harvesting meeting. In particular, let me know if there's any additional information you think we should ask Rob to discuss in the meeting (last slide). If possible, please have this to me by COB Thursday so I can get it to Rob before I go on [redacted](b)(6)

Thanks,

Meg

Harvesting of Aged Materials from Operating and Decommissioning Nuclear Power Plants

M. Audrain, M. Hiser, P.Purtscher, R. Tregoning

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

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Motivation

U.S.NRC
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- Interest in extending lifespan to 60-80 years
  - Need to understand aging mechanisms
  - Key areas: RPV embrittlement, IASCC of internals, concrete structures and containment degradation and electrical cables
- Announced plant shut downs worldwide – opportunities to harvest in situ components
- Limited budgets have restricted new research, including harvesting
  - Important to align interested parties
  - Leverage resources for maximum benefit

NRC Harvesting Experience

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

- NRC has participated in several programs:
  - RPV, CRDM penetrations, RCS piping, RPV internals, neutron absorbers, and cables
  - Materials harvested from unfinished, operating and decommissioning plants
  - US and international programs
- Determined significant value in using harvesting components to confirm data from other research programs

Lessons Learned

U.S.NRC
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- Technical
  - Provides highly representative ages materials for research
  - Important to gain as much information as possible before committing to specific harvesting project
- Logistical
  - Expensive and time-consuming effort
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Current Work

U.S.NRC
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- Develop strategic approach to materials harvesting
  - Past efforts have been reactive to individual plants shutting down
- Prioritize data needs best addressed by harvesting, considering:
  - Applicability of harvested material for addressing gaps
  - Importance of harvested materials over laboratory aging
  - Fleet-wide vs plant-specific applicability of data
  - Regulatory considerations
  - Harvesting cost/complexity
- Database for Sources of Materials
  - Compilation of available materials at US national labs
  - Eventually include materials previously harvested and available for future harvesting
  - NRC is interested in engaging with other organizations in developing the database

Conclusion

U.S.NRC
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- Harvesting can yield highly representative and valuable data on materials aging
- A focused approach to choosing harvested materials is necessary to get best outcomes
- NRC is working on a Sources of Materials Database and a Data Needs Prioritization scheme
- NRC welcomes opportunities for cooperation and leveraging with other interested research organizations

Discussion

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- What (if any) activities are currently being undertaken in Japan for materials harvesting?
- Does Japan have an interest in harvesting? If so, what areas are considered most important?
- Would there be interest in leveraging resources if a harvesting project was identified?

From: Hiser, Matthew
Sent: Thu, 18 Feb 2016 17:27:38 +0000
To: Gardocki, Stanley
Cc: Hull, Amy;Obodoako, Aloysius;Tregoning, Robert;Frankl, Istvan
Subject: LTRP SECY

Hi Stan,

Per our discussion, for the harvesting LTRP, please marked it as OPEN, not closed, and replace the final paragraph with the text below:

This research began in 2015 under a contract with Pacific Northwest National Laboratory for planned completion in 2017. The project is ongoing with three reports to be delivered in 2016 and 2017. This initial scoping study focuses on a literature review of data needs and a strategic plan for capturing important information for harvesting opportunities.

Thanks!
Matt

Matthew Hiser
Materials Engineer
US Nuclear Regulatory Commission | Office of Nuclear Regulatory Research
Division of Engineering | Corrosion and Metallurgy Branch
Phone: 301-415-2454 | Office: TWFN 10D62
Matthew.Hiser@nrc.gov

Subject: Materials Harvesting Workshop
Location: HQ-3WFN-1C03-32p

Start: Tue 3/7/2017 8:00 AM
End: Tue 3/7/2017 5:00 PM
Show Time As: Tentative

Recurrence: (none)

Meeting Status: Not yet responded

Organizer: Hiser, Matthew
Resources: HQ-3WFN-1C03-32p

Subject: Materials Harvesting
Location: T10D40

Start: Wed 5/16/2018 9:00 AM
End: Wed 5/16/2018 10:00 AM
Show Time As: Tentative

Recurrence: (none)

Meeting Status: Not yet responded

Organizer: Hiser, Matthew
Required Attendees Purtscher, Patrick; Tregoning, Robert; Audrain, Margaret; Sircar, Madhumita; Pires, Jose; Koshy, Thomas; Murdock, Darrell; Philip, Jacob

Rescheduling for hopefully a better time for everyone.

We'd like to meet with electrical and concrete research staff to discuss the latest status of the materials harvesting activities under Task 2 of UNR NRR-2017-006.

The four topics we'd like to update you on / discuss in this meeting are:

1. CMB staff development of prioritization criteria for harvesting needs and lessons learned from exercising them for metals
2. CMB staff effort to development inventory of previously harvested materials already available at lab facilities
3. Latest status of harvesting plans for electrical and concrete components
4. Pulling relevant information from license renewal documents for decommissioning plants

From: Hiser, Matthew
Sent: Tue, 17 Jan 2017 15:22:18 -0500
To: Purtscher, Patrick
Subject: Meeting Tomorrow with Pradeep

Hi Pat,

Feel free to give me a call at (b)(6) when you meet with him. I'll answer if I can.

Thanks!
Matt

Matthew Hiser
Materials Engineer
US Nuclear Regulatory Commission | Office of Nuclear Regulatory Research
Division of Engineering | Corrosion and Metallurgy Branch
Phone: 301-415-2454 | Office: TWFN 10D62
Matthew.Hiser@nrc.gov

From: Moyer, Carol
Sent: Tue, 22 Nov 2016 23:14:17 +0000
To: Brock, Kathryn
Cc: Boyce, Tom (RES)
Subject: Notes from OIP discussion re: E. Bradley, IAEA

Kathryn,

Last week, I met with Eric Freeman in OIP to discuss your upcoming trip to Vienna, and a side meeting you have scheduled with Ed Bradley. Eric showed me his position on an organizational chart, reporting to Mikhail Chudakov, Dep. Dir. General & Head of Dept. of Nuclear Energy. Eric compared Ed's role to that of an ETA.

Eric noted that NRC typically works with the Dept. of Nuclear Safety & Security (NS), rather than NE. But it seems that the informal wall has come down somewhat.

The question posed by Ed Bradley is whether NRC has work underway (or planned) for which IAEA could perform a coordinating role. If so, it is possible that our project could be merged into one of their coordinated research projects (CRPs). Benefits may include broader participation and sharing of information, both to benefit the research and to share the research results widely to those who may be able to apply them. CRPs come with elevated priority, commitment of funds, and defined length (usually ~3 yr), in contrast to relatively informal Practical Arrangements. Eric offered to ask Ed for a full list of CRPs already formed. I found that lists of active and proposed CRPs are already available on the IAEA website, here:
https://www.iaea.org/services/coordinated-research-activities
http://cra.iaea.org/cra/explore-crps/all-active-by-programme.html
http://cra.iaea.org/cra/explore-crps/all-opened-for-proposals.html

Eric and I discussed several topics that might be candidates for CRPs or other cooperation with IAEA.

- SMRs – Our EDO seems more inclined to work on the NEA front than IAEA on SMRs, but we do have an expert on the SMR Regulators Forum.
- Knowledge management – Jody Hudson does some work for IAEA-NE related to KM.
- LTO / SLR – It is possible that IAEA could help with identifying and harvesting material from decommissioning plants.
    - Belgium's SCK-CEN mentioned at the General Conference that they have a project to collect RPV specimens.
    - M. Hiser says that our program with EPRI (ZIRP) is focused only on internals, not the RPV. Belgium's Tractabel is participating.
    - Our attempts to get RPV material from Zion, and then from Zorita, fell through. He is not sure, however, of the priority for this. If it is interesting, this is a possible topic for international collaboration.
    - NRC is planning a workshop on ex-plant material harvesting, during the week of March 6, 2017.

In addition to CRPs, Eric mentioned another avenue for collaboration may be to host a workshop. He noted a perception that IAEA-hosted workshops often do not garner much

interest. Member State-hosted workshops organized under IAEA, however, seem to achieve a higher profile. Eric suggested we think about opportunities and topics for this.

Carol

From: Iyengar, Raj
Sent: Thu, 29 Oct 2015 16:10:11 -0400
To: Tregoning, Robert;Kirk, Mark;Fairbanks, Carolyn;Hull, Amy;Medoff, James;Min, Seung;Cheruvenki, Ganesh;Purtscher, Patrick;Rao, Appajosula;Brady, Bennett;Burton, William;Rudland, David;Frankl, Istvan;Yoo, Mark;Holston, William;Allik, Brian;Thomas, Brian;Brock, Kathryn;Hiser, Allen;Jones, Heather;Billoch, Araceli;Gordon, Matthew;Hiser, Matthew
Subject: Notes from the Phone-Call with DOE/EPRI on Metals Topics

All,

Thank you very much for participating and supporting the discussion with DOE/EPRI on the metals topics.

Follow-up items:

INTERNALS

1) ORNL to provide report and presentation on environmentally-assisted fatigue research activity.
2) EPRI to reach out to NRC on ideas/proposals related to modeling of fracture toughness in two-phase materials undergoing irradiation.
3) EPRI to provide information on the research activities related to X750.
4) NRC to engage EPRI and DOE on the ex-plant harvesting activity sometime during the first quarter of CY2016. This topic will not be part of the upcoming (to be scheduled) deep-dive discussion on aging of core internals and piping.

RPV LATE BLOOMING PHASES PRESENTATION

1) RES and NRR technical staff to have an internal meeting on the next steps in developing a technical position on the LBP issue. A possible meeting with EPRI (Robin) on this topic during mid-January 2016.
2) ORNL (Keith) to provide responses to staff's questions.

Thanks so much.

Raj

Note to requester: Attachment is immediately following.

From: Hiser, Matthew
Sent: Tue, 12 Jul 2016 21:13:14 +0000
To: Hull, Amy;Purtscher, Patrick;Tregoning, Robert
Subject: NRAJ Bilateral Meeting Presentation on Harvesting
Attachments: Harvesting Efforts NRAJ Bilateral 7-12-16.pptx

Hi Amy, Pat, and Rob,

I've pulled together a few slides for discussion of the harvesting program at the NRAJ meeting next month.

Please take a look and provide any comments or edits.

Thanks!
Matt

Strategic Approach for Ex-Plant Materials Harvesting

Matthew Hiser

Amy Hull

Patrick Purtscher

Robert Tregoning

U.S. NRC

NRC-NRAJ Bilateral Technical Information Exchange Meeting
Nuclear Regulatory Commission Headquarters
August 8-9, 2016

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Purpose

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- Create a framework for a strategic approach to harvesting ex-plant materials to support regulatory needs associated with subsequent license renewal (SLR)
  - Ex-plant materials offer unique environmental exposure that cannot be entirely replicated by laboratory testing with fresh materials

- Align high priority data needs identified in SLR activities with harvesting opportunities from decommissioning plants

Background

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- To date, harvesting opportunities have been limited due to few decommissioning plants
  - Zion in U.S., Zorita in Spain
- However, several U.S. plants have already shut down or are planning to do so in the near future
  - Kewaunee, San Onofre, Crystal River, Vermont Yankee, Oyster Creek, Fort Calhoun, Clinton, Quad Cities, Diablo Canyon
- This provides a unique opportunity to plan harvesting to address the highest priority technical and regulatory issues

Harvesting Experience

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- Past harvesting efforts have generally involved reactive decision-making
  - Limited opportunities to acquire ex-plant materials
  - Limited strategic planning for harvesting
- Harvesting projects with NRC involvement:
  - Reactors internal materials from Zorita
  - Concrete from Zorita
  - Neutron absorber material from Zion
  - Cables from Zion and Crystal River

Zorita Internals Research Project Timeline

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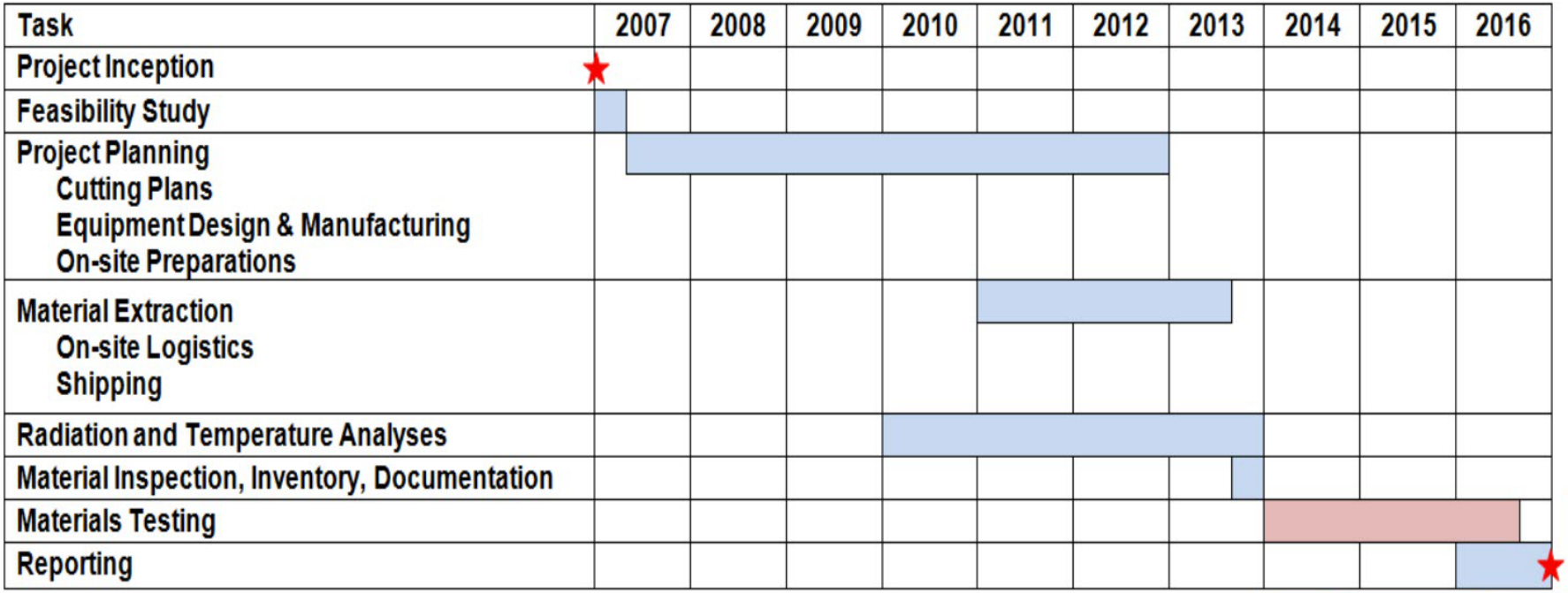

Approach: Assessment of Technical Issues and Available Materials for Harvesting

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- Utilize various sources of technical information with respect to anticipated degradation in NPPs out to 80 years of operation
  - NRC, DOE, EPRI, IAEA
- Identify high-priority data needs that could be addressed through harvesting ex-plant materials
  - Focus on identifying characteristics of important systems, structures, and components (SSCs) for harvesting
- Gather information on ex-plant material expected to be available based on identified needs
  - May be from both operating and decommissioning reactors

Implementation

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- What might the output of this activity look like?
  - For example, the review may show there is value in acquiring CASS material around 15% delta ferrite with various dose ranges (<0.08 dpa, 1–3 dpa, and >5 dpa)
- Once that need is identified, this activity would identify what SSCs might be the best candidates for harvesting
  - For example, perhaps lower support columns would be identified as the ideal SSC to address the CASS data need
- As decommissioning plants announce their plans, there is a clear list of SSCs and their characteristics (metallurgy, temperature, fluence, etc.) that would be desired to address the data need

Current NRC Activities

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- NRC is working with Pacific Northwest National Lab (PNNL) to identify technical issues that may be best addressed by ex-plant harvesting
  - Focused on unique value of harvesting to understand material properties in difficult to replicate environments
- NRC also seeking interest from other stakeholders to better understand availability of materials for harvesting
  - Considering a public workshop in fall 2016
  - Stakeholders include EPRI, DOE, U.S. industry, international partners

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Questions?

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Backup Slides

Neutron Absorbers from Zion

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- **Materials Harvested**:
  - Select Boral® NAM panels from Regions 1 and 2 of the Zion SFP
- **Scope**:
  - Visual and microstructural examinations (incl. areal density)
  - Corrosion testing
- **Purpose**:
  - Identify degradation mechanisms and estimate degradation rate
  - Confirm results of in-situ areal density measurements
  - Provide confirmatory data to support regulatory decision-making
- **Timeline**:
  - Initial discussions in 2014, harvesting in 2015, testing in 2015-2016
- **Coordination**:
  - EPRI, ZionSolutions, SRNL

Zorita Internals Research Project (ZIRP)

U.S.NRC
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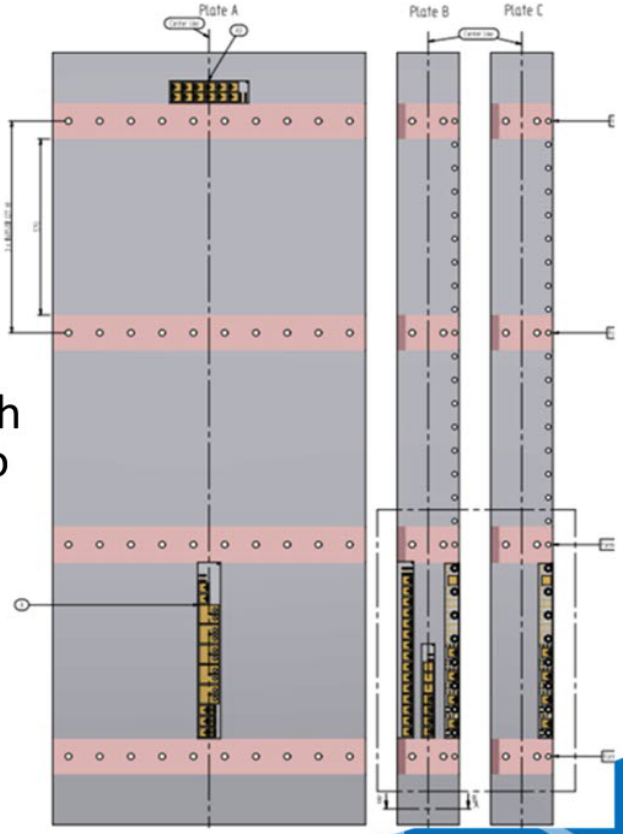
- **Materials Harvested**:
  - Baffle plate and core barrel weld materials
- **Scope**:
  - Mechanical testing (tensile, CGR, FT)
  - Microstructural characterization (void swelling)
- **Purpose**:
  - High-fluence (up to 50 dpa) IAD effects with representative LWR exposure conditions to
  - Support regulatory decision-making associated with SLR
- **Timeline**:
  - Initial discussions in 2006, harvesting in 2013, testing ongoing through 2016
- **Coordination**:
  - EPRI, international consortium, Studsvik, Halden



Concrete from Zorita (Plan)

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- **Materials Harvested**:
  - Concrete from structures that are in close proximity to RPV
- **Scope**:
  - Mechanical testing (compressive, tensile, modulus of elasticity)
  - Microstructural characterization
  - Physical change
- **Purpose**:
  - High fluence in combination with temperature and humidity that are representative of LWR environmental effects on structural and shielding performance
  - Supports regulatory decision-making associated with SLR
- **Timeline**:
  - Initial discussions in 2014, harvesting in 2015, testing 2016-2018
- **Coordination**:
  - NRC , ENRESA and CSN

Cables: Zion and Crystal River

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- **Materials Harvested**:
  - Low and Medium Voltage Cables
- **Scope**:
  - Condition monitoring to assess cable performance under normal operating conditions (accelerated aging) and accident conditions
- **Purpose**:
  - Cable degradation due to normal operating environment and accident conditions
  - Supports regulatory decision-making associated with SLR
- **Timeline**:
  - Initial discussions in 2012; Cable samples harvested from Zion in 2013
  - Plan is to harvest additional samples from Crystal River and Zion in 2015
  - Testing expected to be completed in 2017
- **Coordination**:
  - ORNL, Zion Solutions, NIST, EPRI

Note to requester: Attachments are immediately following.

From: Tregoning, Robert
Sent: Tue, 13 Dec 2016 21:09:04 +0000
To: '坂本 一信'
Subject: NRC Harvesting Workshop
Attachments: Harvesting Workshop Announcement.docx, Condensed Workshop Agenda 12-12-16.docx

Kazu:

As discussed in our August meeting, we're holding a workshop on harvesting in March of 2017. I just sent the following announcement to Olli Nevander to distribute to CSNI members:

On March 7 – 8, 2016, the U.S. NRC, in cooperation with the U.S. Department of Energy (DOE) and the Electric Power Research Institute (EPRI), is hosting an invited workshop on Material and Component Harvesting in Rockville, MD, USA. Harvesting is the extraction of materials, components, or structures from either operational or decommissioned nuclear plants. There is a long history of research programs using harvested materials. Often, these programs are complicated, costly, and risky, and there is a danger that the knowledge gained by the research is not justified by the effort and cost involved. In the near future, there will be more opportunities to obtain harvested materials from nuclear plants, both in the U.S. and internationally. The objective of the workshop is to identify technical needs best addressed by harvesting, identify possible sources of harvested materials, summarize lessons-learned and practical aspects of harvesting programs, and ultimately outline a process for developing a more efficient plan for harvesting materials.

An announcement for the workshop and a condensed agenda is attached. Please contact Rob Tregoning (rlt@nrc.gov), if you are interested in getting more information about the workshop or possibly contributing to the discussion.

Please contact me if you're interested in attending or would like to discuss further. I think it would be good to get a perspective from Asia on some of these topics so it would be good to discuss the best way to do this.

Warm regards,

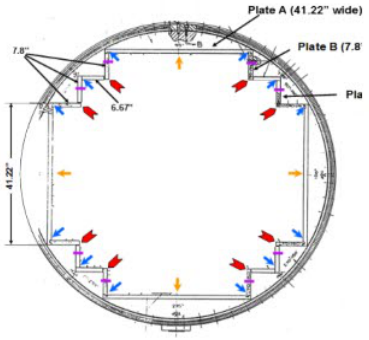
Rob

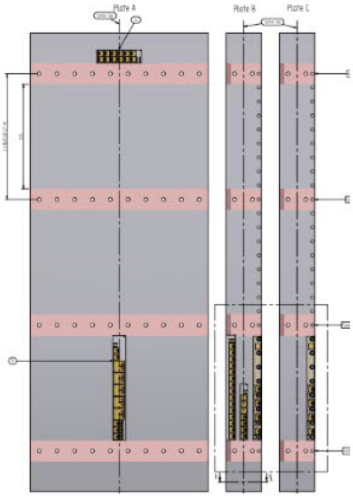
Robert Tregoning
Technical Advisor for Materials
US Nuclear Regulatory Commission
Two White Flint North, M/S T-10 A36
11545 Rockville Pike
Rockville, MD 20852-2738
ph: 301-415-2324
fax: 301-415-6671

Ex-Plant Materials Harvesting Workshop

Location: NRC Headquarters in Rockville, MD, USA

Dates: March 7-8, 2017





Motivation:

- There are increasing opportunities to harvest the safety-critical components from decommissioning plants, both domestic and international.
- The harvested materials are valuable because they have been exposed to actual in-service plant operating conditions (temperature, irradiation, coolant, etc.), unlike virgin materials tested under simulated conditions in the lab.
- Data from ex-plant materials should help address technical gaps identified for extended operation of nuclear power plants due to highly relevant aging conditions.

Purpose and Objective:

- For NRC staff and interested stakeholders to have greater awareness and knowledge of the benefits and challenges associated with ex-plant harvesting.
- Facilitate contacts and communication to enable specific cooperative ex-plant harvesting programs to be initiated.

Workshop Topics:

- Harvesting decision-making and prioritization
  - Technical data needs best addressed by harvesting
  - Technical information needed in advance of harvesting
- Sources of materials:
  - Decommissioning reactors
  - Operating reactors – replaced components
  - Previous harvesting programs – “boneyards”
  - Tracking available materials
- Harvesting process
  - Lessons learned from harvesting experience
  - Perspective of utility-owner and decommissioning contractor on harvesting
  - Communication and coordination between decommissioning and researchers
- International collaborative programs on specific components at specific plants

Workshop will consist of solicited presentations followed by discussion periods. If interested in attending or learning more about the workshop, please reach out to the contacts below.

Contacts: Robert Tregoning, Robert.Tregoning@nrc.gov
Matthew Hiser, Matthew.Hiser@nrc.gov
Patrick Purtscher, Patrick.Purtscher@nrc.gov

Draft Agenda – March 7-8, 2017 Harvesting Workshop

Tuesday, March 7, 2017
Introduction

- Overview of workshop purpose and objectives

Session 1: Motivation for Harvesting

- Solicited presentations from EPRI, DOE, NRC, and international organizations followed by panel discussion

Session 2: Technical data needs best addressed by harvesting

- Solicited presentations from EPRI, DOE, NRC, and international organizations followed by open discussion

Session 3: Sources of Materials

- Solicited presentations from EPRI, DOE, NRC, and international organizations followed by open discussion

Wednesday, March 8, 2017

Session 4: Harvesting Experience: Lessons learned and practical aspects

- Solicited presentations from EPRI, DOE, NRC, U.S. utility, decommissioning companies, and international organizations followed by open discussion

Session 5: Future Harvesting Program Planning

- Solicited presentations from EPRI, DOE, NRC, and international organizations followed by open and panel discussion

Note to requester: Attachment is immediately following. Power Point comments are included on the page following the slide with the comments.

From: Tregoning, Robert
Sent: Wed, 11 Oct 2017 04:59:16 -0600
To: Hiser, Matthew
Cc: Moyer, Carol;Hull, Amy;Purtscher, Patrick
Subject: NRC PLiM slides on Harvesting rlt).pptx
Attachments: NRC PLiM slides on Harvesting rlt).pptx

Matt:

I have only a few comments (attached). I think the key messages are on point. My only real quibble is stylistic. The slides are basically a ton of words. It would be nice to have some representative graphics or illustrations of some of the points just to break up the words. However, I know it can take time to develop/find good representative graphics and given our limited window, I don't know if you want to tackle this or not. At a minimum, I recommend eliminating many of the sub-bullets and sub-sub-bullets from the slides themselves and moving them to the talking points. This will help Allen out as well.

Good job with this on such short notice!

Rob

Robert Tregoning
Technical Advisor for Materials
US Nuclear Regulatory Commission
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U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Harvesting of Aged Materials from Operating and Decommissioning Nuclear Power Plants

M. Hiser[a], P. Purtscher[a], P. Ramuhalli[b], A. B. Hull[a], R. Tregoning[a]
[a]U.S. Nuclear Regulatory Commission (NRC), Washington, D.C., USA
[b]Pacific Northwest National Laboratory (PNNL), Richland, WA, USA

Outline

- Background and Motivation
- NRC Harvesting Experience
- Recent NRC Activities
  - Criteria for Prioritizing Data Needs
  - Database for Sources of Materials
- Path Forward

Background and Motivation

- Recent trends in global nuclear industry:
  - Interest in extending nuclear power plant (NPP) lifespans
    - Technical basis for managing aging of systems, structures, and components for longer time
  - Numerous NPPs, both in U.S. and internationally, have announced plans to or already have shut down
    - New opportunities for harvesting components that were aged in representative light water reactor (LWR) environments
- Limited budgets have restricted the resources available to support new research, including harvesting programs
  - Aligning interests and leveraging with other organizations is important to maximize value

NRC Harvesting Experience

- NRC has participated in numerous harvesting programs over the years:
  - RPV, CRDM penetrations, RCS piping, RPV internals, neutron absorbers, and cables
  - From operating and decommissioning plants in U.S. and internationally TR1
- Significant value in using harvested components to confirm data from other research programs
  - Harvesting materials from highly representative long-term aging environments increases confidence in safety margins

Slide 4

TR1 Also from plants which never began commercial operation

Tregoning, Robert, 10/11/2017

Technical Lessons Learned

- Harvesting can provide highly representative aged materials for research
  - May be only practical source of representative aged materials, particularly if irradiation and temperature TR3 important factors
    - Achieving high fluence levels with representative irradiation conditions through other means is very challenging
  - May be able to use limited harvested materials to validate larger accelerated aging data set
- Important to gain as much information as possible in advance before committing to specific harvesting project
  - Ideally a bounding, yet realistic, material/environment
  - Understand material information (CMTRs if available) and plant operating conditions

TR3 temperature can be simulated easily; it's long-term, slow acting environmental stressors that are the challenge

Tregoning, Robert, 10/11/2017

Logistical Lessons Learned

- Harvesting is an expensive, time-consuming effort
  - Must balance cost with potential benefits carefully
  - High technical relevance of materials is needed to ensure value
- Leveraging resources with other research organizations helps mitigate cost challenges
  - Can introduce challenges for testing when aligning research priorities and interests of multiple organizations
  - May be needed, particularly for expensive testing of irradiated materials
- Transporting irradiated materials, particularly internationally, is cumbersome and time-consuming
  - Avoiding extra transport, especially between countries, is highly recommended

Recent NRC Activities

- Strategic approach to materials harvesting
  - Due to limited opportunities, past harvesting efforts have generally been reactive to individual plants shutting down
- Prioritize the data needs best addressed by harvesting
  - Criteria for harvesting prioritization developed by PNNL
- Workshop held in March 2017 at NRC HQ to discuss all aspects of harvesting with other interested stakeholders
  - Good discussion of experience, including challenges and pitfalls, from those with firsthand knowledge

Potential Criteria for Harvesting Prioritization

- Applicability of harvested material for addressing critical gaps
  - Harvesting for critical gaps 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
- Unique field aspects of degradation
  - For example, unusual operating experience or legacy materials (fabrication methods, etc.) no longer available
- Fleet-wide vs. plant-specific applicability of data

Potential Criteria for Harvesting Prioritization

- Harvesting cost and complexity
  - For example, harvesting unirradiated concrete or electrical cables less expensive and less complex than harvesting from the reactor internals
- Availability of reliable in-service 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

Database for Sources of Materials

- NRC is pursuing the development of a database for sources of materials for harvesting
  - Includes both previously harvested materials and those available for future harvesting
- Allow for aligning of high-priority data needs to the available sources of materials
  - The level of detail should be appropriate for the factors influencing decision-making
- NRC is interested in engaging with other organizations in developing the database

Conclusion and Path Forward

- Harvesting can yield highly representative and valuable data on materials aging
  - Having a clearly defined objective and early engagement with other stakeholders are keys to success
- Data Needs Prioritization and Sources of Materials Database
  - NRC is interested in working with other organizations to identify high-priority data needs of common interest
- As specific harvesting opportunities are identified, NRC welcomes opportunities for cooperation and leveraging with other interested research organizations

From: Tregoning, Robert
Sent: Fri, 24 Aug 2018 19:43:01 +0000
To: Audrain, Margaret;Hiser, Matthew;Purtscher, Patrick
Cc: Frankl, Istvan
Subject: NRC/JNRA meeting during week of 9/17
Importance: High

Meg/Matt/Pat:

Chris Regan and I are traveling to Japan in mid-September to meet with JNRA as part of our biannual materials research exchange. One of the agenda topics is material harvesting. In preparation for the meeting, I am hoping that you can provide me with slides that summarize the state of our research activities and near-term plans. I'm hoping that much, if not all of this information will come from recycled talks and not require much additional burden on your end.

I'd also like you to consider the following questions related to RPV integrity:

1. What information would you like to get from JNRA?
2. What actions (e.g., future information, commitments, data sharing) would you like to see arise from this meeting?

You could include your questions for 1 and 2 as part of your presentation or you could simply send them to me in advance of the meeting.

I'm requesting that you provide me with this information by COB on 9/7. This will give me a week before the trip to make sure that we're aligned on the topic. I think it would be good if one of you coordinates all the input and I'm recommending Meg (since I'm going to hit Matt up on IAD) ☺, but please just let me know you guys decide as lead for this request.

Thanks so much for your help on this. Please let me know if you have further questions as well.

Cheers,

Rob

Robert Tregoning
Technical Advisor for Materials
US Nuclear Regulatory Commission
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11545 Rockville Pike
Rockville, MD 20852-2738
ph: 301-415-2324
fax: 301-415-6671

Subject: NSUF Specimen Library
Location: Telecon: 888-677-8615 passcode: (b)(6)

Start: Thu 11/9/2017 1:00 PM
End: Thu 11/9/2017 2:00 PM
Show Time As: Tentative

Recurrence: (none)

Meeting Status: Not yet responded

Organizer: Hiser, Matthew
Required Attendees Jackson, John Howard; 'kelly.cunningham@inl.gov'; Purtscher, Patrick; Tregoning, Robert; Audrain, Margaret; Simon Martin Pimblott

Updated with bridge line info.

Dear John and Kelly,

Would you be available sometime later this week or next week for a call to discuss the NSUF NFML and how it may be possible to coordinate with our ex-plant harvesting effort here at NRC?

Hopefully, you recall the harvesting workshop that NRC hosted back in March. As a first step on a database for sources of materials, we're looking to reach out in the near future to a few national labs regarding their "boneyards" of previously harvested materials. We hoped to discuss what lessons you may have learned from developing the NFML as well as any synergies that could exist with our harvesting efforts.

Thanks!
Matt

Subject: Placeholder for Harvesting WG
Location: HQ-OWFN-09B02-12p

Note to requester: Attachment is immediately following.

Start: Wed 3/16/2016 10:00 AM
End: Wed 3/16/2016 11:00 AM
Show Time As: Tentative

Recurrence: (none)

Meeting Status: Not yet responded

Organizer: Hiser, Matthew
Required Attendees: Hull, Amy; Oberson, Greg; Collins, Jay; Litkett, Bernard; Tregoning, Robert; Kalikian, Roger; Obodoako, Aloysius
Optional Attendees: Frankl, Istvan; Cumblidge, Stephen; McHale, John; Poehler, Jeffrey
Resources: HQ-OWFN-09B02-12p

Strategic Approach for Obtaining Material and Components Aging Information to Support Reactor Operation Beyond 60 years

Agenda – NRC Task Group
10:00 am, Wednesday, March 16, 2016
OWFN-09B02

I. Task Group (NRR, RES, others)
   - Purpose:
     - provide input to determine gaps for operation beyond 60
   - key areas:
     - RPV at high fluence
     - IAD of internals and other components
     - concrete
     - electrical cable

II. PNNL Work
   - scoping Study
   - evaluate relevant plant material projected to be available for harvesting
   - develop database of lowest knowledge of degradation with availability at plants
   - develop demo prototype taxonomy

III. Public Workshop, Tentative Summer 2016
   - purpose:
     - discuss industry experience from plant harvesting activities
     - discuss future planned activities

IV. Develop Harvesting Plan
   - schedule of plant decommissioning
   - strategic approach to interview and schedule for harvesting of SSCs
   - system design
   - SSC and environments
   - materials
   - records

V. Questions

Subject: Placeholder for Harvesting WG
Location: HQ-OWFN-09B02-12p

Start: Wed 3/16/2016 10:00 AM
End: Wed 3/16/2016 11:00 AM
Show Time As: Tentative

Recurrence: (none)

Meeting Status: Not yet responded

Organizer: Hiser, Matthew
Required Attendees: Hull, Amy; Oberson, Greg; Collins, Jay; Litkett, Bernard; Tregoning, Robert; Kalikian, Roger; Obodoako, Aloysius
Optional Attendees: Frankl, Istvan; Cumblidge, Stephen
Resources: HQ-OWFN-09B02-12p

Rescheduling based on timeline for examples for this group to review and discuss.

Subject: Placeholder for Harvesting WG
Location: HQ-OWFN-09B06-12p

Start: Wed 2/24/2016 9:00 AM
End: Wed 2/24/2016 10:00 AM
Show Time As: Tentative

Recurrence: (none)

Meeting Status: Not yet responded

Organizer: Hiser, Matthew
Required Attendees: Hull, Amy; Oberson, Greg; Collins, Jay; Stevens, Gary; Litkett, Bernard; Tregoning, Robert; Kalikian, Roger
Optional Attendees: Frankl, Istvan; Cumblidge, Stephen
Resources: HQ-OWFN-09B06-12p

Rescheduling based on timeline for examples for this group to review and discuss.

Subject: Placeholder for Harvesting WG
Location: HQ-OWFN-09B02-12p

Start: Wed 2/3/2016 10:00 AM
End: Wed 2/3/2016 11:00 AM
Show Time As: Tentative

Recurrence: (none)

Meeting Status: Not yet responded

Organizer: Hiser, Matthew
Required Attendees: Hull, Amy; Oberson, Greg; Collins, Jay; Stevens, Gary; Litkett, Bernard; Tregoning, Robert; Kalikian, Roger
Optional Attendees: Frankl, Istvan; Cumblidge, Stephen
Resources: HQ-OWFN-09B02-12p

After talking with PNNL, let's push back one more week so they have time to provide some examples for this group to review and discuss.

Subject: Placeholder for Harvesting WG
Location: HQ-OWFN-09B02-12p

Start: Wed 1/27/2016 9:00 AM
End: Wed 1/27/2016 10:00 AM
Show Time As: Tentative

Recurrence: (none)

Meeting Status: Not yet responded

Organizer: Hiser, Matthew
Required Attendees: Hull, Amy; Oberson, Greg; Collins, Jay; Stevens, Gary; Litkett, Bernard; Tregoning, Robert; Kalikian, Roger
Optional Attendees: Frankl, Istvan; Cumblidge, Stephen
Resources: HQ-OWFN-09B02-12p

Subject: Placeholder for Harvesting WG
Location: HQ-OWFN-09B02-12p

Note to requester: Attachment is immediately following.

Start: Mon 3/21/2016 1:30 PM
End: Mon 3/21/2016 2:30 PM
Show Time As: Tentative

Recurrence: (none)

Meeting Status: Not yet responded

Organizer: Hiser, Matthew
Required Attendees: Hull, Amy; Oberson, Greg; Collins, Jay; Litkett, Bernard; Tregoning, Robert; Kalikian, Roger; Obodoako, Aloysius
Optional Attendees: Frankl, Istvan; Cumblidge, Stephen; McHale, John; Poehler, Jeffrey
Resources: HQ-OWFN-09B02-12p

Hi All,

I apologize for the last-minute reschedule.

Aloysius Obodoako recently joined CMB and will be taking the lead for this project (starting with this meeting), but he (b)(6) has [redacted]. It looks like there is a time early next week that works well for almost everyone, so let's try for then.

Thanks!
Matt

Strategic Approach for Obtaining Material and Components Aging Information to Support Reactor Operation Beyond 60 years

Agenda – NRC Task Group
10:00 am, Wednesday, March 16, 2016
OWFN-09B02

I. Task Group (NRR, RES, others)
   - Purpose:
     - provide input to determine gaps for operation beyond 60
   - key areas:
     - RPV at high fluence
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     - concrete
     - electrical cable

II. PNNL Work
   - scoping Study
   - evaluate relevant plant material projected to be available for harvesting
   - develop database of lowest knowledge of degradation with availability at plants
   - develop demo prototype taxonomy

III. Public Workshop, Tentative Summer 2016
   - purpose:
     - discuss industry experience from plant harvesting activities
     - discuss future planned activities

IV. Develop Harvesting Plan
   - schedule of plant decommissioning
   - strategic approach to interview and schedule for harvesting of SSCs
   - system design
   - SSC and environments
   - materials
   - records

V. Questions

From: Purtscher, Patrick
Sent: Thu, 9 Nov 2017 10:20:41 -0500
To: Hiser, Matthew;Audrain, Margaret
Subject: plan for meeting at ANL on harvesting

Meet with ANL to brief them on our plans for harvesting:

BAC KGROUND
March 2017 workshop –
four main areas of consideration for extended service life: RPV, RVI, cables, & concrete

PNNL report –
Lays out a procedure to optimize harvesting outcome, prioritize needs, survey of what's available

GOALS for ANL meeting
What does ANL have from past programs with NRC, DoE, or other source

SGT program looked at tubes pulled from Maguire
Omesh looked at CASS from Shippingport

Doesn't have to be material from ex-plant with extensive service history. Example is FAVOR code for RPV embrittlement. Results from modeling and simulations are dependent on input of the flaws that could be present from fabrication. Sections of old, thick ferritic steel welds from structures with similar acceptance criteria but were never put into service provided important inputs that permitted the computer code to be validated.

A good example of where harvesting is important would be how the BWRVIP is responding to NRC concern for IGSCC mitigation with on-line noble chemistry program. They harvested samples from all regions of operating BWRs to demonstrate the distribution of noble metal particles within the whole system. The presence of a pattern of small, discrete deposits of noble metal particles would indicate good resistance to IGSCC. The individual samples by themselves were not that significant, but taken together, they show that there is effective mitigation in those areas of the system where inspection relief is being requested.

OUTCOME
We hope to assembly an inventory of available materials to consider for harvesting program like that in INL USUF material library. Our emphasis is in the four areas outlined earlier, but not limited to those four. Future OpE can change the focus of harvesting needs very quickly.

From: Hiser, Matthew
Sent: Thursday, November 09, 2017 8:01 AM
To: Purtscher, Patrick <Patrick.Purtscher@nrc.gov>
Subject: RE: phone call with INL

Hi Pat,

They've all accepted the meeting. I need to set up a bridge line, so you'll see an update to the scheduler…

Thanks!
Matt

Matthew Hiser
Materials Engineer
US Nuclear Regulatory Commission | Office of Nuclear Regulatory Research
Division of Engineering | Corrosion and Metallurgy Branch
Phone: 301-415-2454 | Office: TWFN 10D62
Matthew.Hiser@nrc.gov

From: Purtscher, Patrick
Sent: Thursday, November 09, 2017 8:00 AM
To: Hiser, Matthew <Matthew.Hiser@nrc.gov>
Subject: phone call with INL

What have you heard from INL about a phone call? I am working from home today but could call in.

Pat

Subject: Planning/Setup for Harvesting Workshop
Location: HQ-3WFN-1C03-32p

Start: Mon 3/6/2017 2:00 PM
End: Mon 3/6/2017 4:00 PM
Show Time As: Tentative

Recurrence: (none)

Meeting Status: Not yet responded

Organizer: Hiser, Matthew
Required Attendees Tregoning, Robert; Purtscher, Patrick
Resources: HQ-3WFN-1C03-32p

Note to requester: Attachment is immediately following. The attachment was also released in full in interim responses #2 and in #7.

From: Hiser, Matthew
Sent: Fri, 20 Oct 2017 18:25:38 +0000
To: Frankl, Istvan
Subject: PLiM Paper
Attachments: IAEA PLiM Hiser 10-20-2017.docx

Hi Steve,

I've attached the PLiM harvesting paper (adapted from previous poster and slides). This has been reviewed by Rob and technical staff and all comments incorporated.

I've sent this to Gracie to start the concurrence package that can be signed on Monday, but wanted to share with you today in case that might expedite things on Monday. The deadline for PLiM papers was Wednesday (two days ago), so I'd like to get it approved and submitted ASAP. (I'm not too worried about the paper being late given the extremely short timeframe we were given about the possibility of a paper just 10 days ago).

Thanks!
Matt

HARVESTING OF AGED MATERIALS FROM OPERATING AND DECOMMISSIONING NUCLEAR POWER PLANTS

M. Hiser, P. Purtscher, A. B. Hull, R. Tregoning
U. S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research
Washington, DC
Email: matthew.hiser@nrc.gov

P. Ramuhalli
Pacific Northwest National Laboratory
Richland, WA, USA

Abstract

Recent plans to shut down a number of nuclear power plants (NPPs) provide opportunities for harvesting components that were exposed to actual light water reactor (LWR) environments. Technical issues associated with extended plant operation, such as reactor pressure vessel (RPV) embrittlement, irradiation-assisted degradation of reactor internals and primary components, concrete structures and containment degradation, and electrical cable aging, may be used to focus harvesting efforts on high-priority issues. Harvesting can provide highly representative aged materials for research and, in some cases, may be the only practical source of representative aged materials to address high-priority issues. Harvesting can be expensive and time-consuming, which makes it essential to focus on those technical needs with the highest importance and cooperate with multiple organizations whenever possible to optimally leverage resources. NRC is interested in engaging with other organizations to prioritize data needs for harvesting, identify areas of common interest, and develop a database for sources of materials for harvesting.

1. BACKGROUND

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 U.S., there is strong interest in extending NPP lifespans through subsequent license renewal (SLR) from 60 to 80 years [1]. Further research may be required to understand age-related degradation throughout the SLR period to help ensure that aging management programs are adequate. U.S. utilities and the U.S. Nuclear Regulatory Commission (NRC) are focused on the aging of systems, structures, and components in four key technical areas: reactor pressure vessel (RPV) embrittlement, irradiation-assisted degradation of reactor internals and primary components, concrete structures and containment degradation, and electrical cable aging [2]. In recent years, a number of NPPs, both in the U.S. and internationally, have shut down or announced plans to shut down. Unlike in the past when there were very few decommissioning plants, these plant shutdowns provide opportunities for harvesting components that were exposed to actual light water reactor (LWR) environments. Additionally, harvesting programs can be costly and complex. Given these constraints, aligning interests and leveraging with other organizations is important to allow maximum benefit and value for future research programs.

2. NRC EXPERIENCE WITH HARVESTING

NRC has significant experience with harvesting plant components and performing research on harvested materials to address technical issues. This experience includes a range of components from plants in various stages of operation both in the U.S. and internationally. Some of the harvesting projects that the NRC has participated in have studied the following materials or components:

- RPV materials from the decommissioned Gundremmingen plant to study fluence rate effects on RPV embrittlement [3],
- Cast austenitic stainless steel (CASS) materials from the decommissioned Shippingport reactor. to study CASS thermal embrittlement [4],
- RPV materials from the unfinished or never-operated Shoreham and Midland plants to improve understanding of flaw distributions for RPV embrittlement concerns [5-6],
- RPV head control rod drive mechanism penetrations from the operating North Anna and Davis-Besse plants to study primary water stress corrosion cracking (PWSCC) of nickel alloys and the effectiveness of non-destructive evaluation (NDE) methods [8-12],
- Reactor coolant system (RCS) piping nozzle weld materials from the operating V.C. Summer plant to study PWSCC of nickel alloys [11-12],

- Reactor internals materials from the decommissioned Jose Cabrera (known as Zorita) plant to study high-fluence irradiation effects on stainless steel reactor internals materials [13],
- Aluminum-based neutron-absorbing materials from the decommissioned Zion plant to study degradation in the spent fuel pool environment [14],
- Electrical cables from the decommissioned Zion and Crystal River plants to investigate cable degradation [15],
- Electrical bus ducts from the decommissioned Zion plant to study high-energy arc faults in electrical enclosures [16].

As illustrated by these programs, NRC's experience is that harvesting has contributed significantly to improved understanding of important technical issues for nuclear safety. For RPV materials, harvesting has increased knowledge of embrittlement mechanisms and the underlying flaw distributions in the RPV to allow reduction in unnecessary conservatism. For nickel alloys, harvesting has improved understanding of PWSCC and the development of acceptable inspection intervals, while also increasing confidence in the ability of NDE methods to detect and characterize flaws. Finally, recent work on electrical enclosures has helped to identify a potential new safety issue associated with high-energy arc faults in electrical components containing aluminum [16].

3. NRC PERSPECTIVE AND LESSONS LEARNED FROM HARVESTING ACTIVITIES

From NRC's perspective, a principal role of harvesting is to confirm other research results from simulated aging conditions. In many situations, accelerated aging through higher flux test reactor irradiations or elevated temperatures can be used to generate significant data to understand aging effects in a more cost-effective manner. Limited harvesting efforts of materials from actual service environments can help confirm the adequacy of the knowledge gained from accelerated aging studies, and thus increase the confidence in the broader knowledge base.

However, in certain situations, harvesting may be the only practical source of representative aged materials. For example, achieving high fluence levels with representative irradiation conditions through accelerated aging can be very challenging. Additionally, it is essential to gain as much information as possible regarding the materials and environment (temperature, fluence, irradiation conditions, chemistry, humidity, etc.) in advance before committing to a specific harvesting project so that the implications of the results from evaluating the materials can be properly understood.

Pragmatically, harvesting can be expensive, complex, and time-consuming; therefore, focusing on technical needs of high importance will help ensure good value. Likewise, leveraging and cooperation among multiple organizations helps to mitigate cost challenges. It is also quite challenging to transport irradiated materials, particularly internationally, so minimizing or avoiding transportation of irradiated materials is highly recommended.

4. NRC ACTIVITIES ON HARVESTING

NRC is potentially interested in harvesting materials to assess age-related degradation in the four technical areas identified previously: reactor pressure vessel (RPV) embrittlement, irradiation-assisted degradation of reactor internals and primary components, concrete structures and containment degradation, and electrical cable aging [2]. The focus is to understand the impact of extended plant operation on material behavior, including the effects of higher fluences and longer exposures to aging conditions.

NRC has recently undertaken an effort, with the assistance of Pacific Northwest National Laboratory (PNNL), to develop a strategic approach for harvesting aged materials from NPPs. Past harvesting activities have been narrowly focused on the relatively few opportunities to get materials from decommissioning plants. Given the expected availability of materials from numerous plants and identified research needs to better understand aging out to 80 years of operation, the NRC is developing 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.

5. PRIORITIZATION OF DATA NEEDS BEST ADDRESSED BY HARVESTING

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

A number of criteria are being considered for prioritizing the harvesting data needs, including:

— Applicability of harvested material for addressing critical gaps
  - Harvesting to address critical gaps should be prioritized over less essential technical gaps
— Ease of laboratory replication of the degradation scenario
  - Degradation mechanisms that are harder to replicate with simulated aging conditions would be of higher priority for harvesting. For example, simultaneous thermal and irradiation conditions are difficult to replicate outside of the plant environment. Alternatively, accelerated aging may not be feasible for a mechanism sensitive to dose rate. These two degradation mechanisms may be best evaluated using harvested materials.
— Unique field aspects of degradation
  - For example, legacy materials (e.g., fabrication methods, composition) that are no longer available, but may play an important role in a potential degradation mechanism, would have a higher priority than harvesting materials that can be obtained from other sources.
— Fleet-wide vs. plant-specific applicability of data
  - There is greater value in developing knowledge to address an issue that may be applicable to a larger number of plants compared to one that may only affect a relatively small number of plants.
— Harvesting cost and complexity
  - Activities with higher costs and complexity are less attractive than similar activities with lower costs and that are simpler to execute.. For example, harvesting unirradiated concrete or electrical cables is less expensive and less complex than harvesting from the reactor internals or RPV.
— Availability of reliable inspection methods for the degradation scenario
  - If mature inspection methods exist and are easy to apply to monitor degradation, harvesting may be less valuable. If inspection methods do not exist, harvesting may be essential to ensure confidence in the assessment of age-related degradation in that particular component.
— Timeliness of the expected research results
  - The ability of a potential harvesting program to provide timely results to support either a technical or regulatory need is important. Having high confidence that results will be timely increases the priority.
— Availability of materials for harvesting
  - The availability of materials to harvest for a particular data need is clearly essential and increases the priority.

The above potential criteria provide a systematic approach for prioritizing harvesting data needs. Different organizations may weigh these criteria differently, but the criteria are intended to be comprehensive. NRC is interested in engaging with other organizations to further refine these criteria, use them to prioritize data needs for harvesting, and ultimately identify areas of common interest that may provide optimal harvesting opportunities.

6. DATABASE OF SOURCES OF MATERIALS FOR HARVESTING

The NRC is also developing a database that identifies sources of materials for harvesting. This database will include both previously harvested materials and those which may be available for future harvesting. This database will be used to align the high-priority harvesting needs to the available materials. As with the harvesting prioritization effort, the level of detail for the sources of materials database should be appropriate for the factors influencing decision-making. NRC is interested in engaging with other organizations to develop a database that identifies sources of materials for harvesting.

7. CONCLUSIONS

NRC's experience is that harvesting can yield highly representative and valuable knowledge about materials aging. However, these efforts may be expensive and challenging. Having a clearly defined objective and early engagement with other stakeholders, including the decommissioning plant where harvesting will take place, are necessary to ensure project success. As specific harvesting opportunities are identified through this strategic approach, the NRC will develop strategies for pursuing these opportunities. The NRC also welcomes collaboration from other interested research organizations both in developing the proactive harvesting strategy and in pursuing harvesting opportunities of mutual interest.

REFERENCES

[1] REMER, S. J., "NRC Commissioner Briefing on Subsequent License Renewal," NRC Commission meeting on April 26, 2017, https://www.nrc.gov/reading-rm/doc-collections/commission/slides/2017/20170426/remer-20170426.pdf.

[2] U.S. NUCLEAR REGULATORY COMMISSION, "Ongoing Staff Activities to Assess Regulatory Considerations for Power Reactor Subsequent License Renewal," SECY-14-0016, 2014, https://www.nrc.gov/docs/ML1405/ML14050A306.pdf.

[3] HAWTHORNE, J.R., HISER, A.L., "Experimental Assessments of Gundremmingen RPV Archive Material for Fluence Rate Effects Studies," NUREG/CR-5201 (MEA-2286), U.S. Nuclear Regulatory Commission, October 1988.

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[10] CRAWFORD, S.L., 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.

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[15] FIFIELD, L.S., "Status Report and Research Plan for Cables Harvested from Crystal River Unit 3 Nuclear Generating Plant," PNNL-25833, September 2016.

[16] GIITTER, J. G., "Path Forward for Regulatory Treatment of High-Energy Arcing Fault Tests Results that Involve Aluminum," Internal NRC memo, March 2016, https://www.nrc.gov/docs/ML1606/ML16064A250.pdf.

Note to requester: Attachments are immediately following.

From: Hiser, Matthew
Sent: Mon, 11 Dec 2017 18:39:24 +0000
To: Audrain, Margaret;Purtscher, Patrick
Subject: PLiM Slides and Paper on Harvesting
Attachments: IAEA PLiM Harvesting Final.pdf, NRC PLiM slides on Harvesting final.pdf

Here you go – let me know if you have any questions.

Thanks!
Matt

Matthew Hiser
Materials Engineer
US Nuclear Regulatory Commission | Office of Nuclear Regulatory Research
Division of Engineering | Corrosion and Metallurgy Branch
Phone: 301-415-2454 | Office: TWFN 10D62
Matthew.Hiser@nrc.gov

HARVESTING OF AGED MATERIALS FROM OPERATING AND DECOMMISSIONING NUCLEAR POWER PLANTS

M. Hiser, P. Purtscher, A. B. Hull, R. Tregoning
U. S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research
Washington, DC
Email: matthew.hiser@nrc.gov

P. Ramuhalli
Pacific Northwest National Laboratory
Richland, WA, USA

Abstract

Recent plans to shut down a number of nuclear power plants (NPPs) provide opportunities for harvesting components that were exposed to actual light water reactor (LWR) environments. Technical issues associated with extended plant operation, such as reactor pressure vessel (RPV) embrittlement, irradiation-assisted degradation of reactor internals and primary components, concrete structures and containment degradation, and electrical cable aging, may be used to focus harvesting efforts on high-priority issues. Harvesting can provide highly representative aged materials for research and, in some cases, may be the only practical source of representative aged materials to address high-priority issues. Harvesting can be expensive and time-consuming, which makes it essential to focus on those technical needs with the highest importance and cooperate with multiple organizations whenever possible to optimally leverage resources. NRC is interested in engaging with other organizations to prioritize data needs for harvesting, identify areas of common interest, and develop a database for sources of materials for harvesting.

1. BACKGROUND

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 U.S., there is strong interest in extending NPP lifespans through subsequent license renewal (SLR) from 60 to 80 years [1]. Further research may be required to understand age-related degradation throughout the SLR period to help ensure that aging management programs are adequate. U.S. utilities and the U.S. Nuclear Regulatory Commission (NRC) are focused on the aging of systems, structures, and components in four key technical areas: reactor pressure vessel (RPV) embrittlement, irradiation-assisted degradation (IAD) of RPV internals and primary components, concrete structures and containment degradation, and electrical cable aging [2]. In recent years, a number of NPPs, both in the U.S. and internationally, have shut down or announced plans to shut down. Unlike in the past when there were very few decommissioning plants, these plant shutdowns provide opportunities for harvesting components that were exposed to actual light water reactor (LWR) environments. Additionally, harvesting programs can be costly and complex. Given these constraints, aligning interests and leveraging with other organizations is important to allow maximum benefit and value for future research programs.

2. NRC EXPERIENCE WITH HARVESTING

NRC has significant experience with harvesting plant components and performing research on harvested materials to address technical issues. This experience includes a range of components from plants in various stages of operation both in the U.S. and internationally. Some of the harvesting projects that the NRC has participated in have studied the following materials or components:

- RPV materials from the decommissioned Gundremmingen plant to study fluence rate effects on RPV embrittlement [3],
- Cast austenitic stainless steel (CASS) materials from the decommissioned Shippingport reactor. to study CASS thermal embrittlement [4],
- RPV materials from the unfinished or never-operated Shoreham and Midland plants to improve understanding of flaw distributions for RPV embrittlement concerns [5-6],
- RPV head control rod drive mechanism penetrations from the operating North Anna and Davis-Besse plants to study primary water stress corrosion cracking (PWSCC) of nickel alloys and the effectiveness of non-destructive evaluation (NDE) methods [8-12],
- Reactor coolant system (RCS) piping nozzle weld materials from the operating V.C. Summer plant to study PWSCC of nickel alloys [11-12],

- Reactor internals materials from the decommissioned Jose Cabrera (known as Zorita) plant to study high-fluence irradiation effects on stainless steel reactor internals materials [13],
- Aluminum-based neutron-absorbing materials from the decommissioned Zion plant to study degradation in the spent fuel pool environment [14],
- Electrical cables from the decommissioned Zion and Crystal River plants to investigate cable degradation [15],
- Electrical bus ducts from the decommissioned Zion plant to study high-energy arc faults in electrical enclosures [16].

As illustrated by these programs, NRC's experience is that harvesting has contributed significantly to improved understanding of important technical issues for nuclear safety. For RPV materials, harvesting has increased knowledge of embrittlement mechanisms and the underlying flaw distributions in the RPV to allow reduction in unnecessary conservatism. For nickel alloys, harvesting has improved understanding of PWSCC and the development of acceptable inspection intervals, while also increasing confidence in the ability of NDE methods to detect and characterize flaws. Finally, recent work on electrical enclosures has helped to identify a potential new safety issue associated with high-energy arc faults in electrical components containing aluminum [16].

3. NRC PERSPECTIVE AND LESSONS LEARNED FROM HARVESTING ACTIVITIES

From NRC's perspective, a principal role of harvesting is to confirm other research results from simulated aging conditions. In many situations, accelerated aging through higher flux test reactor irradiations or elevated temperatures can be used to generate significant data to understand aging effects in a more cost-effective manner. Limited harvesting efforts of materials from actual service environments can help confirm the adequacy of the knowledge gained from accelerated aging studies, and thus increase the confidence in the broader knowledge base.

However, in certain situations, harvesting may be the only practical source of representative aged materials. For example, achieving high fluence levels with representative irradiation conditions through accelerated aging can be very challenging. Additionally, it is essential to gain as much information as possible regarding the materials and environment (temperature, fluence, irradiation conditions, chemistry, humidity, etc.) in advance before committing to a specific harvesting project so that the implications of the results from evaluating the materials can be properly understood.

Pragmatically, harvesting can be expensive, complex, and time-consuming; therefore, focusing on technical needs of high importance will help ensure good value. Likewise, leveraging and cooperation among multiple organizations helps to mitigate cost challenges. It is also quite challenging to transport irradiated materials, particularly internationally, so minimizing or avoiding transportation of irradiated materials is highly recommended.

4. NRC ACTIVITIES ON HARVESTING

NRC is potentially interested in harvesting materials to assess age-related degradation in the four technical areas identified previously: RPV embrittlement, IAD of RPV internals and primary components, concrete structures and containment degradation, and electrical cable aging [2]. The focus is to understand the impact of extended plant operation on material behavior, including the effects of higher fluences and longer exposures to aging conditions.

NRC has recently undertaken an effort, with the assistance of Pacific Northwest National Laboratory (PNNL), to develop a strategic approach for harvesting aged materials from NPPs. Past harvesting activities have been narrowly focused on the relatively few opportunities to get materials from decommissioning plants. Given the expected availability of materials from numerous plants and identified research needs to better understand aging out to 80 years of operation, the NRC is developing 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.

5. PRIORITIZATION OF DATA NEEDS BEST ADDRESSED BY HARVESTING

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

A number of criteria are being considered for prioritizing the harvesting data needs, including:

— Applicability of harvested material for addressing critical gaps
  - Harvesting to address critical gaps should be prioritized over less essential technical gaps
— Ease of laboratory replication of the degradation scenario
  - Degradation mechanisms that are harder to replicate with simulated aging conditions would be of higher priority for harvesting. For example, simultaneous thermal and irradiation conditions are difficult to replicate outside of the plant environment. Alternatively, accelerated aging may not be feasible for a mechanism sensitive to dose rate. These two degradation mechanisms may be best evaluated using harvested materials.
— Unique field aspects of degradation
  - For example, legacy materials (e.g., fabrication methods, composition) that are no longer available, but may play an important role in a potential degradation mechanism, would have a higher priority than harvesting materials that can be obtained from other sources.
— Fleet-wide vs. plant-specific applicability of data
  - There is greater value in developing knowledge to address an issue that may be applicable to a larger number of plants compared to one that may only affect a relatively small number of plants.
— Harvesting cost and complexity
  - Activities with higher costs and complexity are less attractive than similar activities with lower costs and that are simpler to execute.. For example, harvesting unirradiated concrete or electrical cables is less expensive and less complex than harvesting from the RPV internals or the RPV.
— Availability of reliable inspection methods for the degradation scenario
  - If mature inspection methods exist and are easy to apply to monitor degradation, harvesting may be less valuable. If inspection methods do not exist, harvesting may be essential to ensure confidence in the assessment of age-related degradation in that particular component.
— Timeliness of the expected research results
  - The ability of a potential harvesting program to provide timely results to support either a technical or regulatory need is important. Having high confidence that results will be timely increases the priority.
— Availability of materials for harvesting
  - The availability of materials to harvest for a particular data need is clearly essential and increases the priority.

The above potential criteria provide a systematic approach for prioritizing harvesting data needs. Different organizations may weigh these criteria differently, but the criteria are intended to be comprehensive. NRC is interested in engaging with other organizations to further refine these criteria, use them to prioritize data needs for harvesting, and ultimately identify areas of common interest that may provide optimal harvesting opportunities.

6. DATABASE OF SOURCES OF MATERIALS FOR HARVESTING

NRC is interested in engaging with other organizations to develop a database that identifies sources of materials for harvesting. This database would include both previously harvested materials and those which may be available for future harvesting. This database would be used to align the high-priority harvesting needs to the available materials. As with the harvesting prioritization effort, the level of detail for the sources of materials database should be appropriate for the factors influencing decision-making.

7. CONCLUSIONS

NRC's experience is that harvesting can yield highly representative and valuable knowledge about materials aging. However, these efforts may be expensive and challenging. Having a clearly defined objective and early engagement with other stakeholders, including the decommissioning plant where harvesting will take place, are necessary to ensure project success. As specific harvesting opportunities are identified through this strategic approach, the NRC will develop strategies for pursuing these opportunities. The NRC also welcomes collaboration from other interested research organizations both in developing the proactive harvesting strategy and in pursuing harvesting opportunities of mutual interest.

REFERENCES

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[7] MCCABE, D.E., 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.

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[9] CUMBLIDGE, S.E., 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.

[10] CRAWFORD, S.L., 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.

[11] ALEXANDREANU, B., CHOPRA, O.K., SHACK, W.J., "Crack Growth Rates in a PWR Environment of Nickel Alloys from the Davis-Besse and V.C. Summer Power Plants," NUREG/CR-6921 (ANL-05/55), U.S. Nuclear Regulatory Commission, November 2006.

[12] ALEXANDREANU, B., CHOPRA, O.K., SHACK, W.J., "Crack Growth Rates and Metallographic Examinations of Alloy 600 and Alloy 82/182 from Field Components and Laboratory Materials Tested in PWR Environments," NUREG/CR-6964 (ANL-07/12), U.S. Nuclear Regulatory Commission, May 2008.

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[16] GIITTER, J. G., "Path Forward for Regulatory Treatment of High-Energy Arcing Fault Tests Results that Involve Aluminum," Internal NRC memo, March 2016, https://www.nrc.gov/docs/ML1606/ML16064A250.pdf.

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United States Nuclear Regulatory Commission
Protecting People and the Environment

Harvesting of Aged Materials from Operating and Decommissioning Nuclear Power Plants

M. Hiser[a], P. Purtscher[a], P. Ramuhalli[b], A. B. Hull[a], R. Tregoning[a]
[a]U.S. Nuclear Regulatory Commission (NRC), Washington, D.C., USA
[b]Pacific Northwest National Laboratory (PNNL), Richland, WA, USA

Outline

- Background and Motivation
- NRC Harvesting Experience
- Recent NRC Activities
  - Criteria for Prioritizing Data Needs
  - Database for Sources of Materials
- Path Forward

Background and Motivation

- Recent trends in global nuclear industry:
  - Interest in extending nuclear power plant (NPP) lifespans
  - Numerous NPPs, both in U.S. and internationally, have announced plans to or already have shut down
- Limited budgets have restricted the resources available to support new research, including harvesting programs
  - Aligning interests and leveraging with other organizations is important to maximize value

NRC Harvesting Experience

- NRC has participated in numerous harvesting programs over the years:
  - RPV, CRDM penetrations, RCS piping, RPV internals, neutron absorbers, and cables
  - From unfinished, operating ,and decommissioning plants in U.S. and internationally
- Significant value in using harvested components to confirm data from other research programs

Technical Lessons Learned

- Harvesting can provide highly representative aged materials for research
  - May be only practical source of representative aged materials
  - May be able to use limited harvested materials to validate larger accelerated aging data set
- Important to gain as much information as possible in advance before committing to specific harvesting project

Logistical Lessons Learned

- Harvesting is an expensive, time-consuming effort
- Leveraging resources with other research organizations helps mitigate cost challenges
- Transporting irradiated materials, particularly internationally, is cumbersome and time-consuming

Lifting operation for irradiated materials transport cask

Recent NRC Activities

- Strategic approach to materials harvesting
  - Due to limited opportunities, past harvesting efforts have generally been reactive to individual plants shutting down
- Prioritize the data needs best addressed by harvesting
- Workshop held in March 2017 at NRC HQ to discuss all aspects of harvesting with other interested stakeholders

Potential Criteria for Harvesting Prioritization

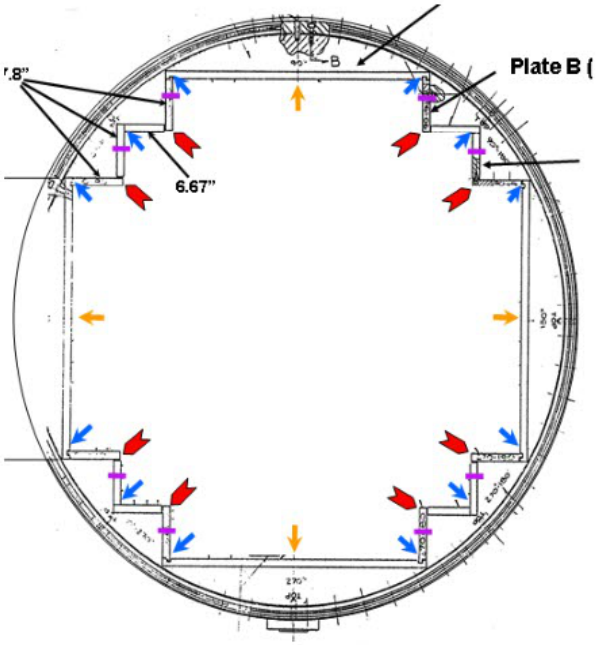
- Applicability of harvested material for addressing critical gaps
- Ease of laboratory replication of the degradation scenario
- Unique field aspects of degradation
- Fleet-wide vs. plant-specific applicability of data

Potential Criteria for Harvesting Prioritization

- Harvesting cost and complexity
- Availability of reliable in-service inspection (ISI) techniques for the material / component
- Availability of materials for harvesting
- Timeliness of the expected research results relative to the objective

Database for Sources of Materials

- NRC is pursuing the development of a database for sources of materials for harvesting
- Allow for aligning of high-priority data needs to the available sources of materials
- NRC is interested in engaging with other organizations in developing the database



Example of reactor internals harvesting plan

Conclusion and Path Forward

- Harvesting can yield highly representative and valuable data on materials aging
- Data Needs Prioritization and Sources of Materials Database
- As specific harvesting opportunities are identified, NRC welcomes opportunities for cooperation and leveraging with other interested research organizations

From: Hiser, Matthew
Sent: Thu, 28 Jun 2018 18:04:02 +0000
To: Frankl, Istvan
Subject: PNNL Emergent Travel

Hi Steve,

I submitted the emergent travel request to our branch spreadsheet (\\nrc.gov\nrc\HQ\Office\RES\RES\DE\CMB\Travel\FY18 RES-DE travel - CMB.xlsx) for this trip. Darrell Dunn and Bruce Lin (CIB) will also be attending this inspection demonstration by EPRI. I want to emphasize that this travel has value for the harvesting program as well.

Also, a reminder Raj discussed this with Chris last Thursday and got buy-in from Chris and the NMSS BC Hipolito Gonzalez.

Please let me know if there's anything else I need to do to help support this request.

Thanks!
Matt

From: Tregoning, Robert
Sent: Thu, 7 Sep 2017 08:54:49 -0400
To: Hiser, Matthew;Purtscher, Patrick
Subject: PNNL harvesting report

Guys:

I've skimmed the report and have some thoughts to share. I'd be interested in your thoughts as well….

Rob

Robert Tregoning
Technical Advisor for Materials
US Nuclear Regulatory Commission
Two White Flint North, M/S T-10 A36
11545 Rockville Pike
Rockville, MD 20852-2738
ph: 301-415-2324
fax: 301-415-6671

From: Purtscher, Patrick
Sent: Fri, 24 Mar 2017 12:37:48 -0400
To: Hiser, Matthew;Tregoning, Robert
Subject: RE: ACTION: One-pager on the Harvesting Workshop

This looks good.

Pat

From: Hiser, Matthew
Sent: Friday, March 24, 2017 11:45 AM
To: Tregoning, Robert <Robert.Tregoning@nrc.gov>; Purtscher, Patrick <Patrick.Purtscher@nrc.gov>
Subject: FW: ACTION: One-pager on the Harvesting Workshop

Hi Rob and Pat,

Here is my first stab at the harvesting one-pager Steve mentioned below. Please take a look and edit as needed and I'll send back to Steve.

Thanks!
Matt

From: Frankl, Istvan
Sent: Monday, March 20, 2017 5:24 PM
To: Hiser, Matthew <Matthew.Hiser@nrc.gov>
Subject: ACTION: One-pager on the Harvesting Workshop

Matt,

One of the action items that came out of the bi-weekly CMB/CIB status meeting today was Brian's request for a DE "one-pager" on the harvesting workshop.

Please align on this with Rob and get a draft to me for review by next Monday.

Thanks,

Steve

Note to requester: The attachment is immediately following.

From: Frankl, Istvan
Sent: Fri, 21 Apr 2017 14:03:55 -0400
To: Hiser, Matthew
Subject: RE: ACTION: One-pager on the Harvesting Workshop
Attachments: Harvesting One Pager 4-21-17.docx

Thanks, Matt.

I accepted your revisions and attached the final version which I am going to share with Brian on Monday.

Steve.

From: Hiser, Matthew
Sent: Friday, April 21, 2017 1:56 PM
To: Frankl, Istvan <Istvan.Frankl@nrc.gov>
Subject: RE: ACTION: One-pager on the Harvesting Workshop

Here you go Steve.

Thanks!
Matt

From: Frankl, Istvan
Sent: Friday, April 21, 2017 12:22 PM
To: Hiser, Matthew <Matthew.Hiser@nrc.gov>
Subject: RE: ACTION: One-pager on the Harvesting Workshop

Thanks, Matt.

It's almost done. I have attached my final comments/revisions.

Steve

From: Hiser, Matthew
Sent: Thursday, April 20, 2017 11:41 AM
To: Frankl, Istvan <Istvan.Frankl@nrc.gov>
Subject: RE: ACTION: One-pager on the Harvesting Workshop

Hi Steve,

OK, I've updated the one-pager with your edits and responded to a couple questions.

Thanks!
Matt

Matthew Hiser
Materials Engineer
US Nuclear Regulatory Commission | Office of Nuclear Regulatory Research
Division of Engineering | Corrosion and Metallurgy Branch
Phone: 301-415-2454 | Office: TWFN 10D62
Matthew.Hiser@nrc.gov

From: Frankl, Istvan
Sent: Tuesday, April 18, 2017 5:19 PM
To: Hiser, Matthew <Matthew.Hiser@nrc.gov>
Subject: RE: ACTION: One-pager on the Harvesting Workshop

Sorry for being so late with my review.

I left my mark-ups on your chair.

Thanks,

Steve

From: Hiser, Matthew
Sent: Friday, March 24, 2017 1:51 PM
To: Frankl, Istvan <Istvan.Frankl@nrc.gov>
Subject: RE: ACTION: One-pager on the Harvesting Workshop

Hi Steve,

Here is the one-pager with input from Rob, Pat, and I.

Thanks!
Matt

From: Frankl, Istvan
Sent: Monday, March 20, 2017 5:24 PM
To: Hiser, Matthew <Matthew.Hiser@nrc.gov>
Subject: ACTION: One-pager on the Harvesting Workshop

Matt,

One of the action items that came out of the bi-weekly CMB/CIB status meeting today was Brian's request for a DE "one-pager" on the harvesting workshop.

Please align on this with Rob and get a draft to me for review by next Monday.

Thanks,

Steve

Ex-Plant Materials Harvesting One-Pager

Motivation:

- Ex-plant materials are valuable because they have been exposed to actual in-service plant operating conditions (temperature, irradiation, coolant, etc.)
    - Generally, research involves accelerated, simulated aging conditions in a lab which may not be as representative of actual in-service aging
    - Highly representative materials (actual plant components) and aging conditions reduces the uncertainty associated with the applicability of research findings.
- With plants shutting down both in the U.S. and Europe, there are increasing opportunities to harvest components from decommissioning plants.
- Insights from ex-plant harvesting would support regulatory decisions for subsequent license renewal (SLR), and could have implications for the current license period
    - There is a task in the new draft UNR for SLR from NRR/DLR requesting RES to investigate opportunities for harvesting where appropriate.

Purpose and Objective:

- For NRC staff and interested stakeholders to have greater awareness and knowledge of the benefits and challenges associated with ex-plant harvesting.
- Support initiation of specific cooperative ex-plant harvesting programs by leveraging limited NRC resources to produce highly representative technical data of materials degradation for extended plant operation.

Workshop Summary:

- NRC staff hosted a 2-day workshop on March 7-8, 2017 with interested stakeholders, including domestic and international utilities and research organizations, to discuss benefits and challenges associated with ex-plant harvesting. Views and insights from various parties contributed to the discussion
- Workshop participants gave presentations and actively engaged in open discussion of different aspects of ex-plant materials harvesting
    - Sessions covered motivation for harvesting, data needs, sources of materials, lessons learned, the practical aspects of harvesting, and harvesting decision-making and planning
- The discussion focused on the importance of clearly identifying the need and purpose for performing a harvesting project.
    - All participants agreed harvesting is a complex and expensive proposition, but one that can be worthwhile if the need is clearly defined and addressed.
- The insights from utilities and decommissioning contractors were extremely valuable.
    - NRC staff and stakeholders are better informed and aware of the benefits and challenges associated with ex-plant harvesting.

Path Forward:

- Detailed workshop summary report to be distributed among meeting participants by May 2017
- PNNL report on a strategic approach to ex-plant harvesting to be completed by May 2017
- Developing alignment within NRC on prioritization of harvesting data needs in four primary areas:
    - RPV, RPV internals and other metals, electrical cables and components, concrete
- RES staff will engage with interested workshop participants on prioritizing data needs and developing a database identifying sources of materials for harvesting

From: Frankl, Istvan
Sent: Fri, 21 Apr 2017 14:15:01 -0400
To: Hiser, Matthew
Subject: RE: ACTION: One-pager on the Harvesting Workshop

Thanks, Matt.

We'll do.

Enjoy the weekend.

Steve

From: Hiser, Matthew
Sent: Friday, April 21, 2017 2:10 PM
To: Frankl, Istvan <Istvan.Frankl@nrc.gov>
Subject: RE: ACTION: One-pager on the Harvesting Workshop

Thanks Steve!

I also spoke with Donna-Marie this morning about the SSM email and explained our planned path forward with the return shipping and she said that's OK with IPT, so you can mention that to Brian as well on Monday. If he wants to feed back to Mike, that's fine. I'm also happy to send Mike an email if that's easier.

Thanks!
Matt

From: Frankl, Istvan
Sent: Friday, April 21, 2017 2:04 PM
To: Hiser, Matthew <Matthew.Hiser@nrc.gov>
Subject: RE: ACTION: One-pager on the Harvesting Workshop

Thanks, Matt.

I accepted your revisions and attached the final version which I am going to share with Brian on Monday.

Steve.

From: Hiser, Matthew
Sent: Friday, April 21, 2017 1:56 PM
To: Frankl, Istvan <Istvan.Frankl@nrc.gov>
Subject: RE: ACTION: One-pager on the Harvesting Workshop

Here you go Steve.

Thanks!
Matt

From: Frankl, Istvan
Sent: Friday, April 21, 2017 12:22 PM
To: Hiser, Matthew <Matthew.Hiser@nrc.gov>
Subject: RE: ACTION: One-pager on the Harvesting Workshop

Thanks, Matt.

It's almost done. I have attached my final comments/revisions.

Steve

From: Hiser, Matthew
Sent: Thursday, April 20, 2017 11:41 AM
To: Frankl, Istvan <Istvan.Frankl@nrc.gov>
Subject: RE: ACTION: One-pager on the Harvesting Workshop

Hi Steve,

OK, I've updated the one-pager with your edits and responded to a couple questions.

Thanks!
Matt

Matthew Hiser
Materials Engineer
US Nuclear Regulatory Commission | Office of Nuclear Regulatory Research
Division of Engineering | Corrosion and Metallurgy Branch
Phone: 301-415-2454 | Office: TWFN 10D62
Matthew.Hiser@nrc.gov

From: Frankl, Istvan
Sent: Tuesday, April 18, 2017 5:19 PM
To: Hiser, Matthew <Matthew.Hiser@nrc.gov>
Subject: RE: ACTION: One-pager on the Harvesting Workshop

Sorry for being so late with my review.

I left my mark-ups on your chair.

Thanks,

Steve

From: Hiser, Matthew
Sent: Friday, March 24, 2017 1:51 PM
To: Frankl, Istvan <Istvan.Frankl@nrc.gov>
Subject: RE: ACTION: One-pager on the Harvesting Workshop

Hi Steve,

Here is the one-pager with input from Rob, Pat, and I.

Thanks!
Matt

From: Frankl, Istvan
Sent: Monday, March 20, 2017 5:24 PM
To: Hiser, Matthew <Matthew.Hiser@nrc.gov>
Subject: ACTION: One-pager on the Harvesting Workshop

Matt,

One of the action items that came out of the bi-weekly CMB/CIB status meeting today was Brian's request for a DE "one-pager" on the harvesting workshop.

Please align on this with Rob and get a draft to me for review by next Monday.

Thanks,

Steve

CRIEPI motivations for harvested material research

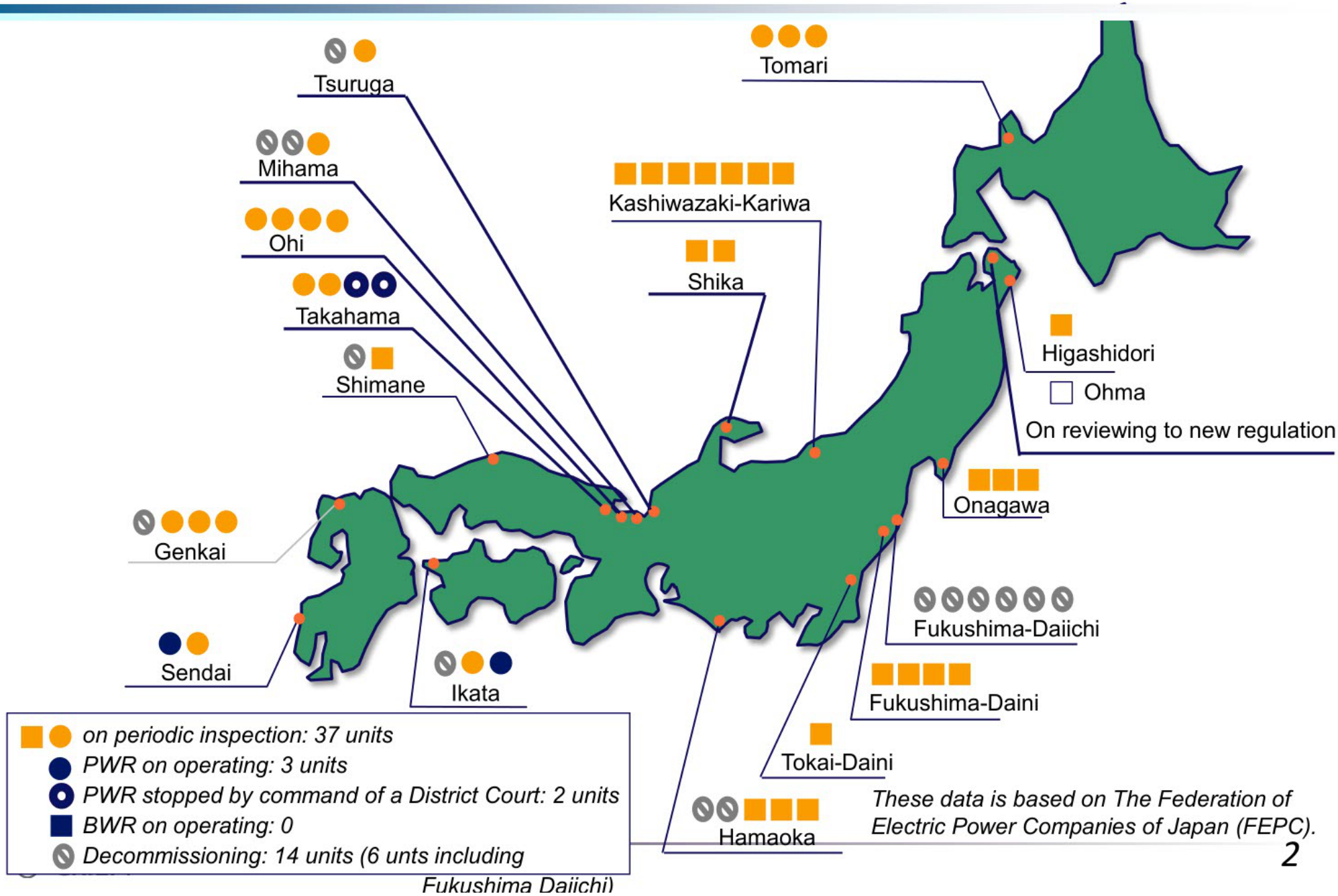
Material Research Lab.
Nuclear Power Plant Maintenance Research Team
Central Research Institute of Electric Power Industry
Taku Arai, Sadao Higuchi

Ex-Plant Materials Harvesting Workshop

March 7-8, 2017 USNRC HQ, Rockville, MD, USA

CRIEPI
Central Research Institute of Electric Power Industry

Current Status of the NPPs in Japan(as of February 8, 2017)



Harvested materials vs Lab. materials

Items	Harvested materials	Laboratory prepared materials
Exposed conditions	Actual plant conditions	Accelerated and/or simulated ; neutron flux, temperature
Choice of material conditions	Fewer choice Material conditions are defined by plant conditions	Easy to prepare desirable conditions
Parametric data acquisition	Not easy	Easy to conducting parametric data acquisition
Number of data	Smaller than lab. data	Larger data base

- ✓ Fact finding
- ✓ Confirmation
- ✓ Verification

- ✓ Understanding degradation behavior under long term operation
- ✓ Understanding mechanism
- ✓ Clarifying initiation conditions and degradation trends
- ✓ Verifying or developing prediction method
- ✓ Developing inspection preventive maintenance methods etc.

Possible research items

- Irradiation embrittlement of RPV
- Irradiation induced stress corrosion cracking (IASCC)
- Thermal aging of cast austenitic stainless steel (CASS) and austenitic stainless steel weld metal (ASSWM) and combination effect of thermal aging and neutron irradiation
- Loss of isolation of cable and I&C components
- Loss of strength of concrete strength
- Fluence evaluation optimization

CRIEPI activites

- Research institute
  - Irradiation embritlement, SCC, IASCC, Thermal aging, Pipe wall thinning, Cable degradation , NDI technique etc.)

- PLM research administrative review meeting
  - Japanese utilities, plant fabricators, CRIEPI, INSS, FEPC, JANSI
  - 10 subgroups (SCC, Irradiation embrittlement, Fatigues, Concrete degradation, Cable insulation degradation, Inspection/monitoring technologies)
  - Research strategy, issue management tables, roadmaps
  - A team for considering harvesting material research

FEPC: Federations of electric power companies of Japan
JANSI: Japan nuclear safety instiute

CRIEPI motivations

- Radiation embrittlement of RPV steels
  - Demonstrating the adequacy of surveillance program
  - Clarifying safety margins including in current evaluation methods
- Irradiation effect for austenitic stainless core internals
  - Clarifying microstructural changes due to neutron irradiation
  - Developing correlation models between microstructural changes and mechanical propeties
- Thermal aging and combination of thermal aging and irradiation for CASS and stainless weld metal.
  - Demonstrating the adequacies of current prediction methods
  - Clarifying safety margins including in current prediction methods
  - Clarifying combination effects of thermal aging and irradiation.

CRIEPI experiences and current activities for harvested material research

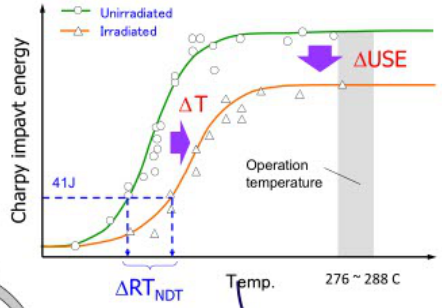
- Experiences (APT analysis)
  - RPV surveillance database(collaboration with all the Japanese utilities)
  - Greifswald(VVER-440) RPV material(collaboration with HZDR)
  - 304L, 304 and 316 stainless steels from decommissioned core internals (collaboration with EPRI)
- Current activity
  - National research project (corroborating with LWRS)
  - RPV embrittlement
    - Through-wall fracture toughness and microstructure characterization for Zion RPV
  - Radiation effect austenitic stainless steels
    - APT analysis for baffle former bolts from a US PWR

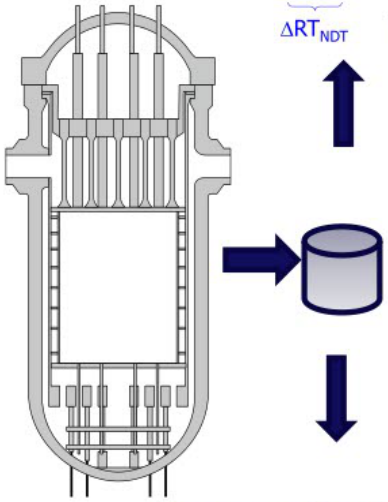
Objectives in each research item

Components, MA phenomena	Understanding behavior/ distribution in actual components	Understanding mechanism	Establishment prediction model	Verification, modification prediction model
RPV, Radiation embrittlement	✔	✔		✔
Core internals, IASCC	✔	✔	✔	
Core internals, Reduction of toughness due to irradiation and/or thermal aging	✔	✔	✔	
CASS component, Thermal aging	✔	✔		✔
Piping, nozzle, Low cycle fatigue	✔			✔
Cable & CI, Loss of isolation	✔	✔		✔
Concrete, Loss of strength	✔	✔	✔	✔
RPV, core internals, concrete etc. Fluence evaluation optimization	✔			✔

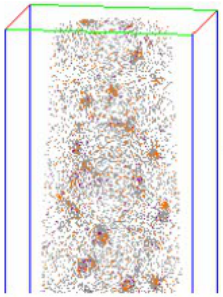
RPV radiation embrittlement
Comparison between measured and calculated value

Charpy impact test

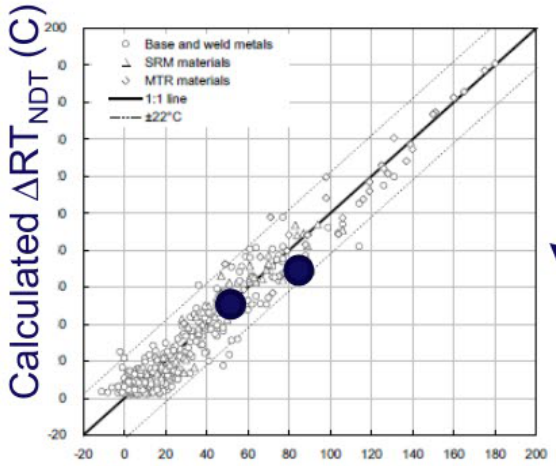




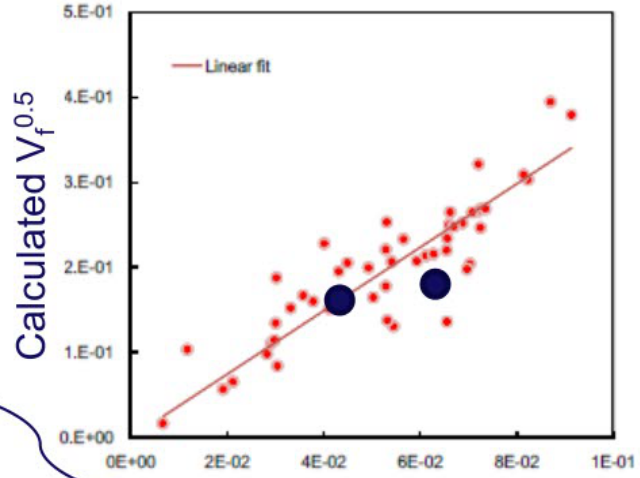
Atom probe tomography



Measured vs calculated value

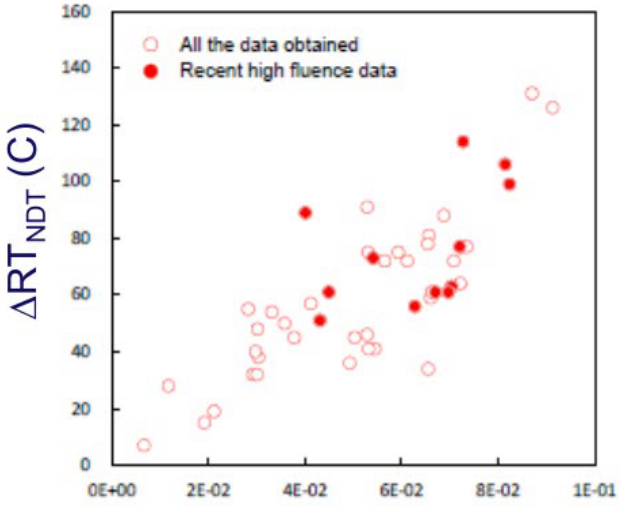


Measured ΔRT_{NDT} (C)



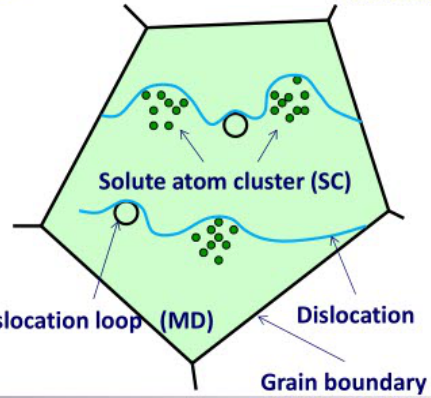
Measured $V_f^{0.5}$

Prediction method, JEAC4201 based on mechanistic model



$V_f^{0.5}$

V_f : Volume fraction of solute atom cluster



Chemical composition
Fluence, Flux,
Irrad. Temp.

Application of research and possible source of samples

Components, MA phenomena	Safety/ LTO	License renewal	Efficiency of operation	Possible source of samples
RPV, Radiation embrittlement	✔	✔		Decommissioned plant
Core internals, IASCC		✔	✔	Decommissioned plant Replaced component
Core internal, Reduction of toughness due to irradiation and thermal aging	✔	✔	✔	Decommissioned plant Replaced component
CASS component, Thermal aging		✔		Decommissioned plant Replaced component
Piping, nozzle, Low cycle fatigue		✔		Decommissioned plant Replaced component
Cable & CI, Loss of isolation	✔	✔		Decommissioned plant Replaced component
Concrete, Loss of strength	✔	✔	✔	Decommissioned plant
RPV, core internals, concrete etc. Fluence evaluation optimization	✔	✔	✔	Decommissioned plant Replaced component

CRIEPI research activities with harvested materials

Material Research Lab.

Nuclear Power Plant Maintenance Research Team

Taku Arai, Sadao Higuchi

Ex-Plant Materials Harvesting Workshop

March 7-8, 2017 USNRC HQ, Rockville, MD, USA

CRIEPI
Central Research Institute of Electric Power Industry

CRIEPI projects

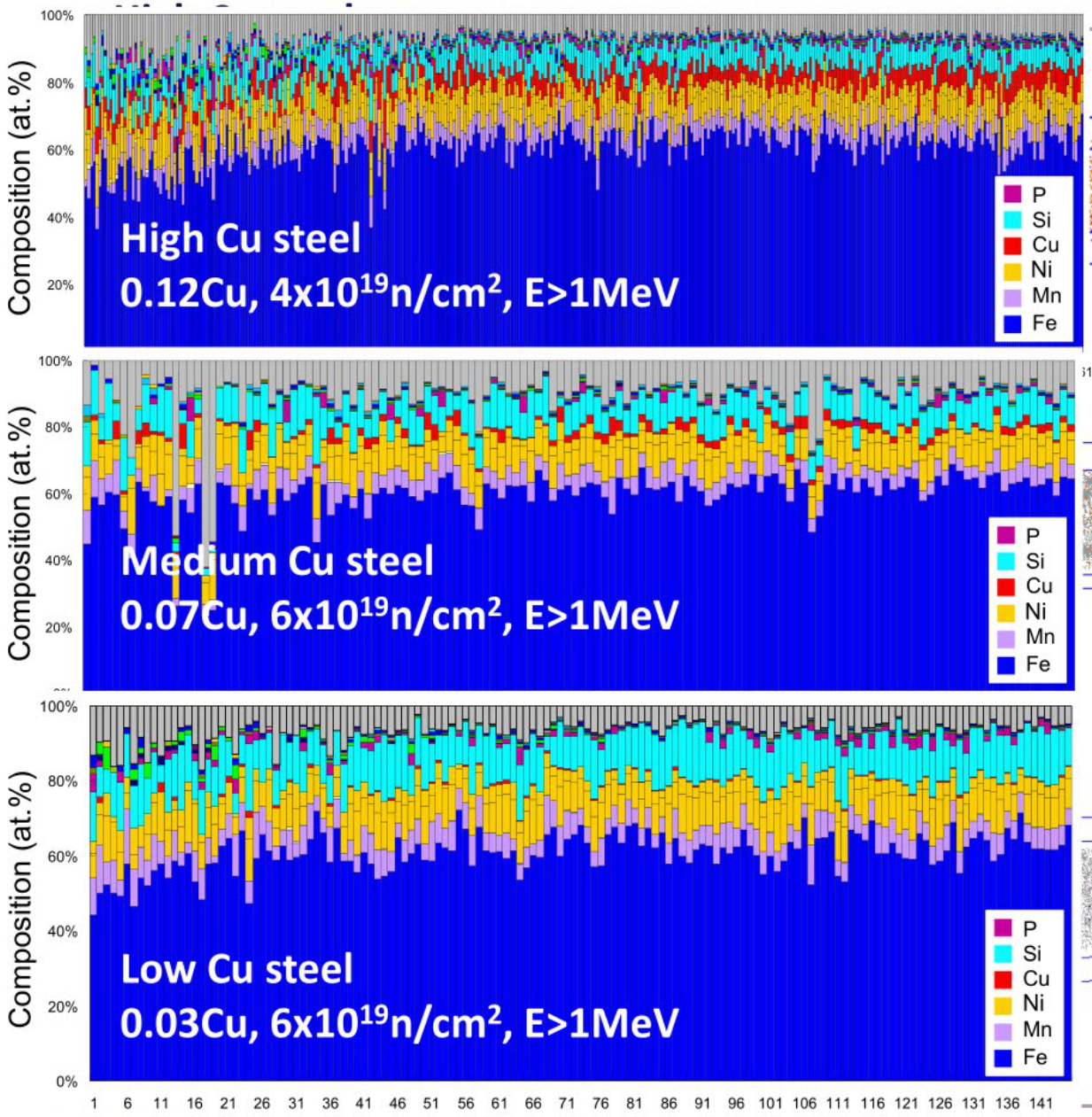
- RPV surveillance database
  - All the Japanese utilities
- Greifswald(VVER/440) RPV material
  - Collaboration with HZDR
- 304L, 304 and 316 stainless steels from decommissioned core internals
  - Collaboration with EPRI
- National research project
  - Irradiation effects on RPV and Core Internals
  - Collaboration with LWRS(ORNL)

RPV SURVEILLANCE MATERIALS

Japanese RPV surveillance database

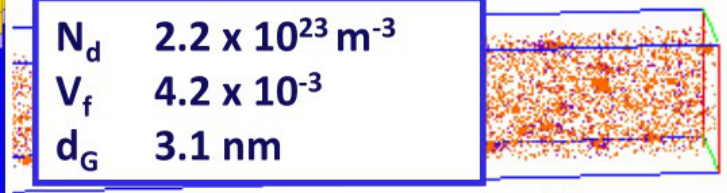
- Microstructural characterization of the RPV surveillance materials has been continuously performed by CRIEPI since 2007.
  - Mainly Atom Probe Tomography (APT)
- More than 100 conditions with different materials and different fluences have been compiled to date.
  - Good correlation between microstructural changes and mechanical changes has been observed.

Nature of solute atom clusters



Cu-Ni-Si-Mn cluster

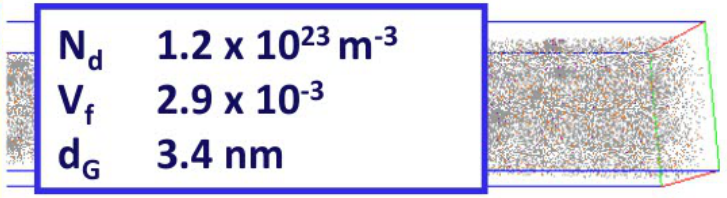
N_d	2.2×10^{23} m^{-3}
V_f	4.2×10^{-3}
d_G	3.1 nm



35 x 41 x 491 nm^3
13.7M atoms

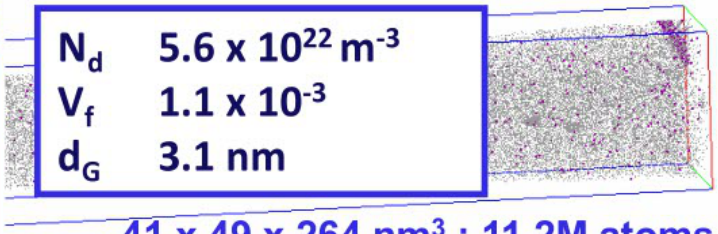
Cu
Si
P

N_d	1.2×10^{23} m^{-3}
V_f	2.9×10^{-3}
d_G	3.4 nm



33 x 38 x 284 nm^3 : 8.1M atoms

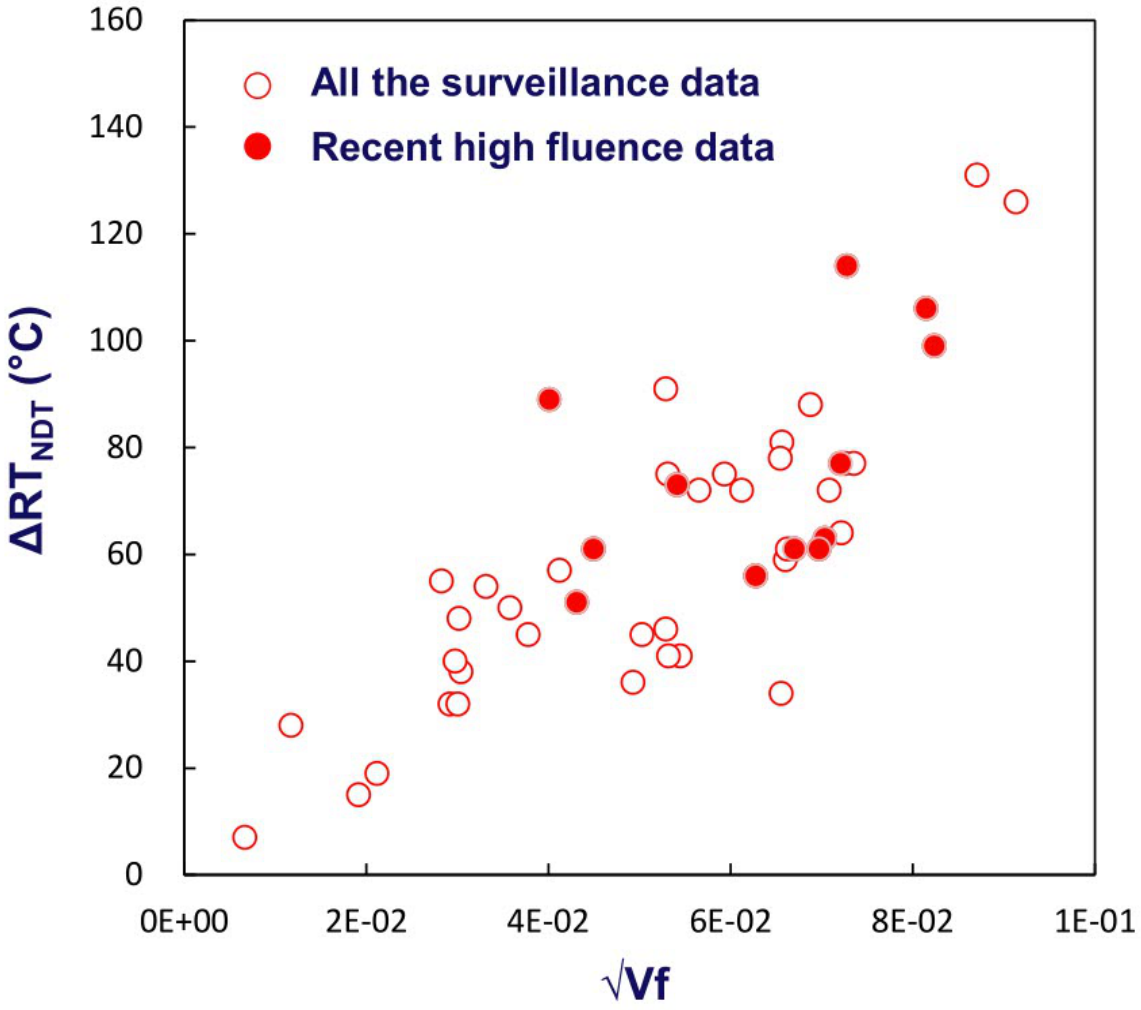
N_d	5.6×10^{22} m^{-3}
V_f	1.1×10^{-3}
d_G	3.1 nm



41 x 49 x 264 nm^3 : 11.2M atoms

Ni-Si-Mn cluster

ΔRT_{NDT} vs V_f



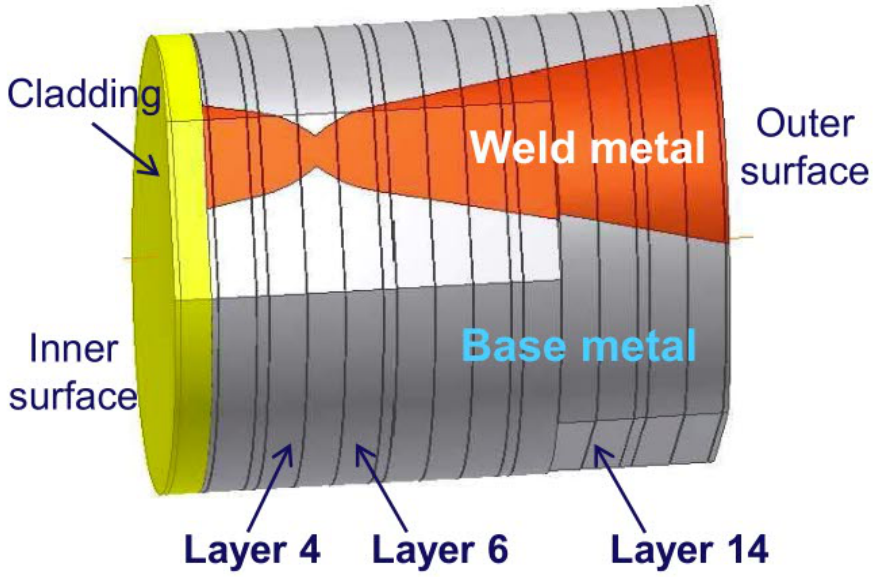
- The correlation between ΔRT_{NDT} and V_f for the recent high fluence data shown in solid red symbols is consistent with that for lower fluence surveillance data.

Greifswald RPV materials

RPV MATERIALS HARVESTED FROM DECOMMISSIONED PLANT

Greifswald Unit 4 material

- **SANS (HZDR), APT (CRIEPI) and Hv (HZDR & CRIEPI) were performed to characterize the weld and base metals of Greifswald Unit 4 RPV.**

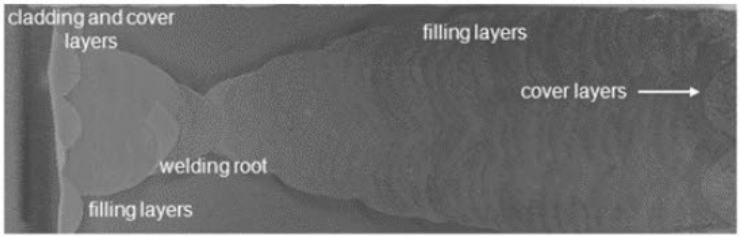


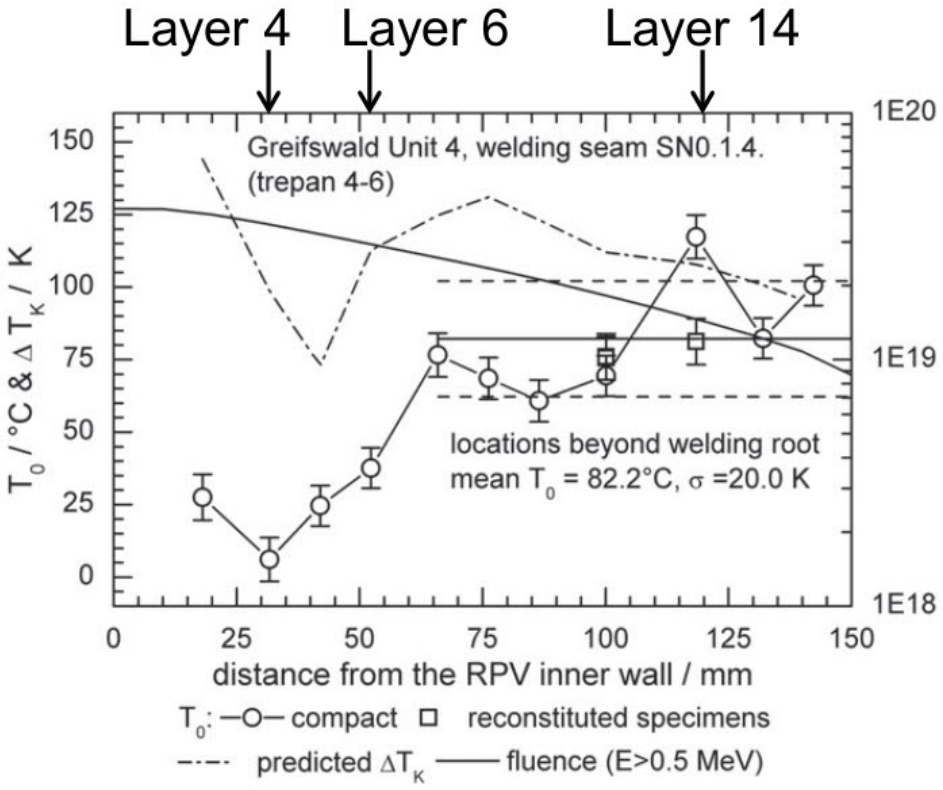
Irradiation temperature 270°C

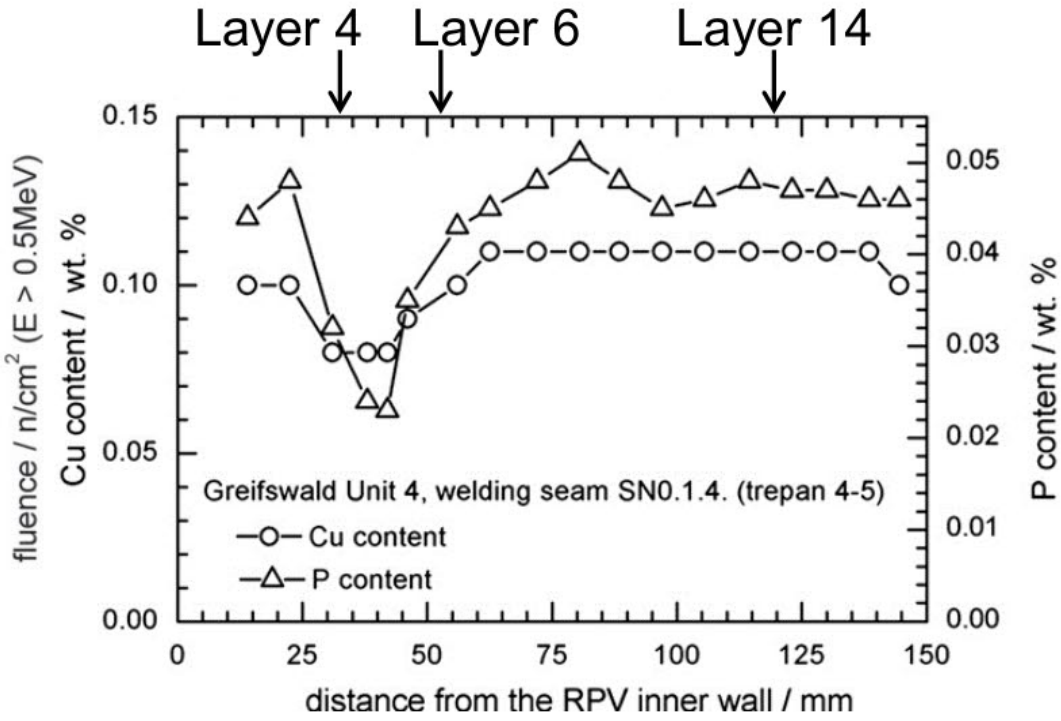
Material	Neutron fluence (10^{19} n/cm^2, E>1MeV)	Neutron flux (10^{11} n/cm^2/s, E>1MeV)
Weld layer 4	2.0	0.72
Weld layer 6	1.5	0.55
Weld layer 14	0.6	0.22
Base layer 4	2.6	0.94

Material	Cu	P	Ni	Mn	C	Si	Cr	Mo	V
Weld	0.12	0.029	0.12	0.98	0.08	0.33	1.31	0.45	0.15
Base	0.1	0.012	0.16	0.47	0.17	0.74	2.52	0.57	0.25

Distributions of mechanical property and chemical composition

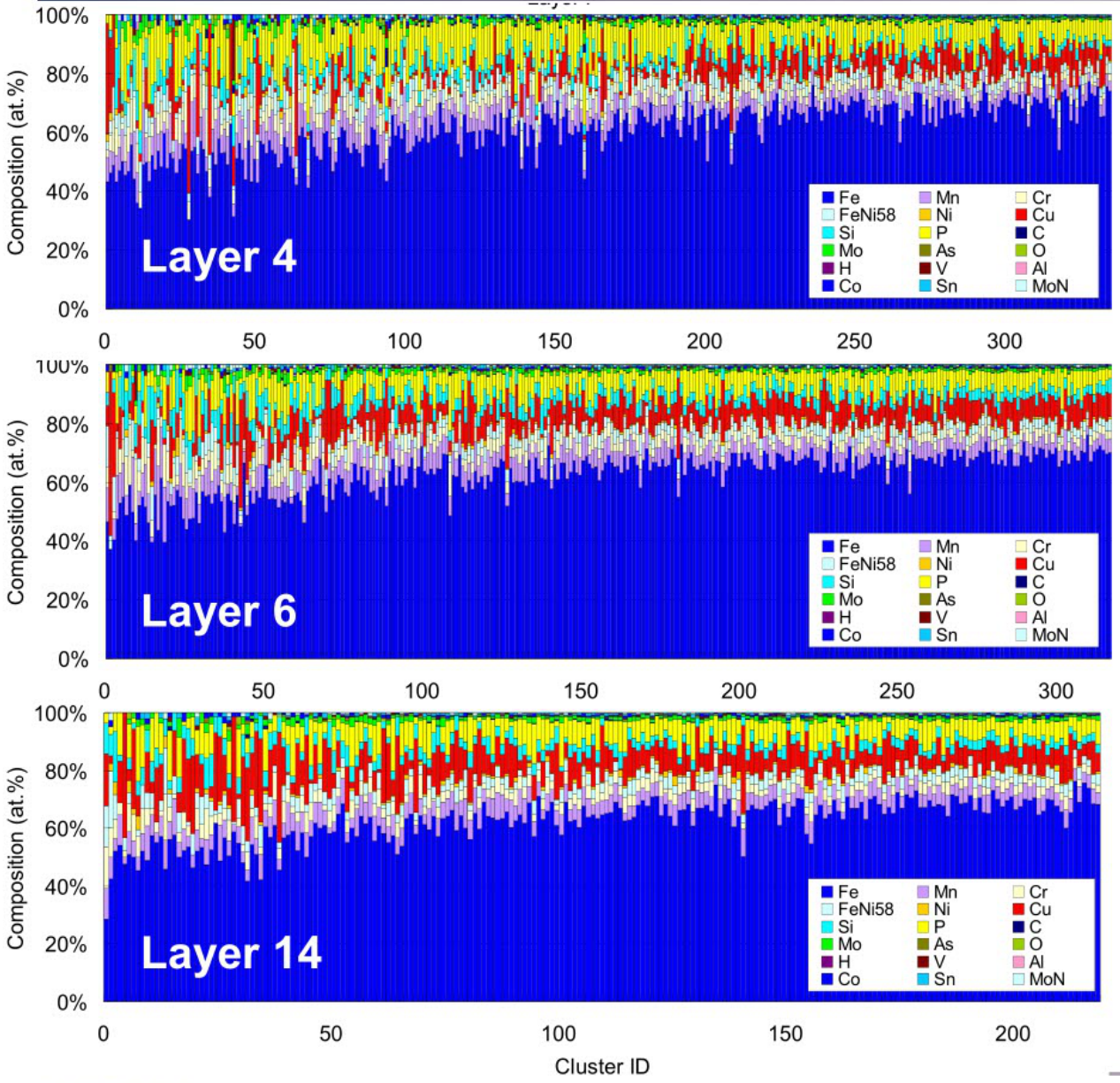






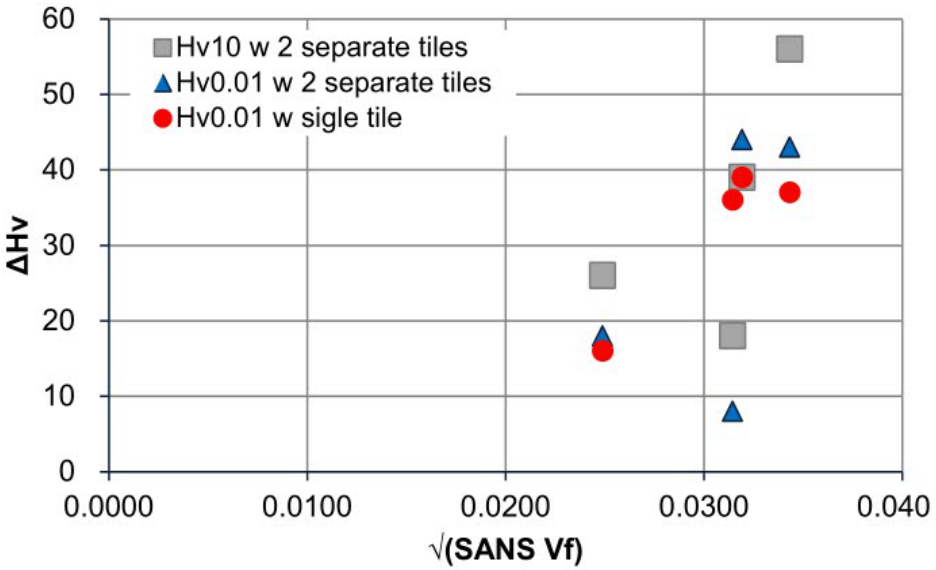
Ref. Viehrig, H.-W.; Altstadt, E.; Houska, M.; Valo, M.: Fracture mechanics characterization of the beltline welding seam of the decommissioned WWER-440 reactor pressure vessels of nuclear power plant Greifswald Unit 4. International Journal of Pressure Vessels and Piping 89(2012)

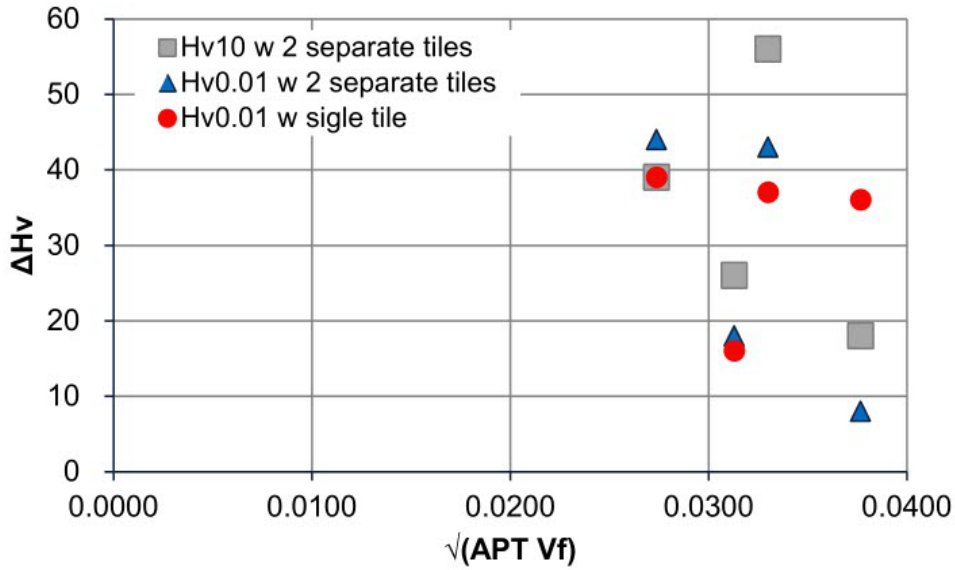
APT results of weld metals



- P content (yellow) is very high in the three materials compared to the Japanese steels.
- Cu content (red) is very low in small clusters of layer 4, while all the clusters contain Cu atoms in layer 6 and 14.

Comparison between SANS, APT and Hv





- **Comparison between the SANS Vf and ΔHv0.01 by single tile method shows relatively good correlation.**
  - **Combination of single tile, NI hardness distribution measurement and PIA is a powerful tool to avoid material variability.**
- **Sampling APT needles from the area of hardness measurement may give us information with less scatter.**

STAINLESS STEELS HARVESTED FROM DECOMMISSIONED CORE INTERNALS

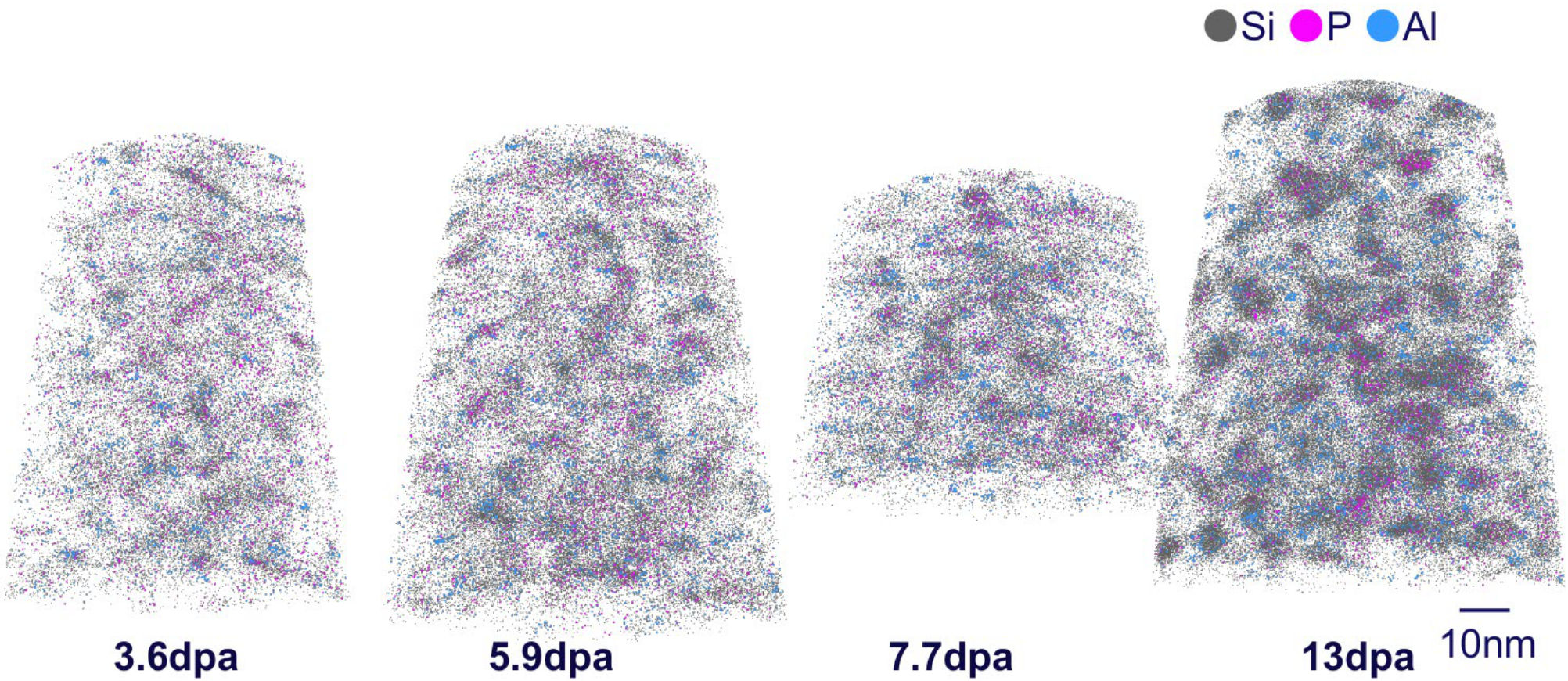
APT Characterization of 304L SS

- Grain interior analysis of 304L SS by APT

ID	Material	Source	Neutron Fluence (n/cm^2, E > 1 MeV)	dpa
A	304L	CR	$2.5X10^{21}$	3.6
B	304	TG	$3.3X10^{21}$	4.7
C	304	TG	$3.8X10^{21}$	5.5
D	304L	CR	$4.2X10^{21}$	5.9
E	304L	CR	$5.4X10^{21}$	7.7
F	304L	CR	$9.1X10^{21}$	13
G	316L	CR	$4.7X10^{21}$	6.7

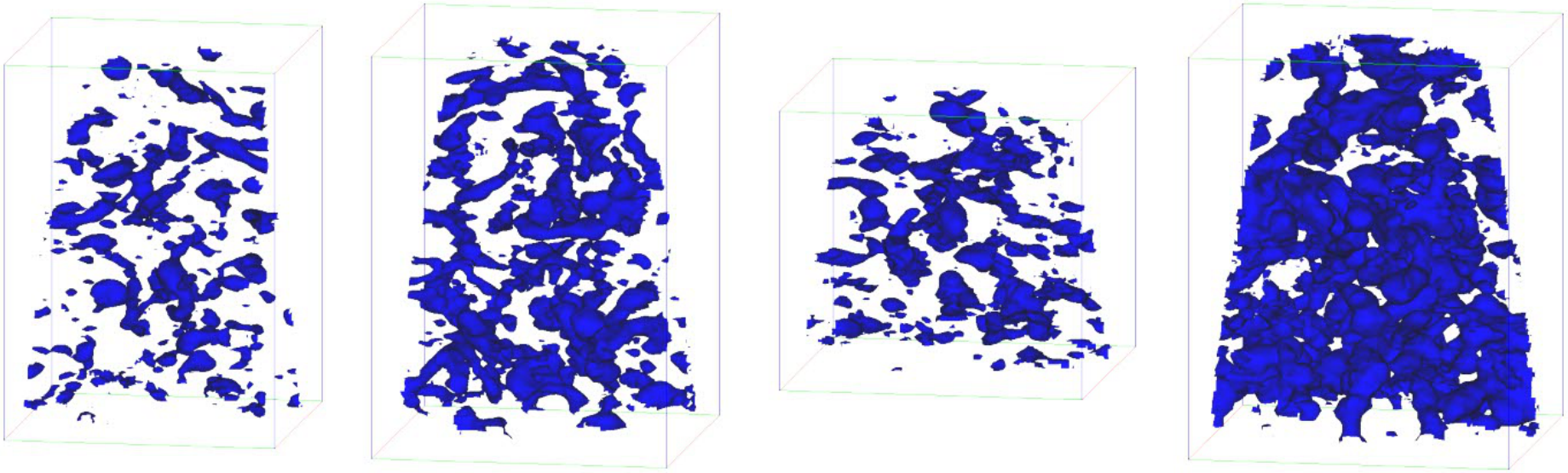
CR: Control rod, TG: Top guide

Comparison of 304L SS microstructures



- Both Ni/Si and Al clusters are well developed at 13 dpa that at lower doses.
- Note that Si and Al bulk compositions is higher in the 304L heat irradiated to 13 dpa.

Iso-surface of 2 at% Si in 304L SS



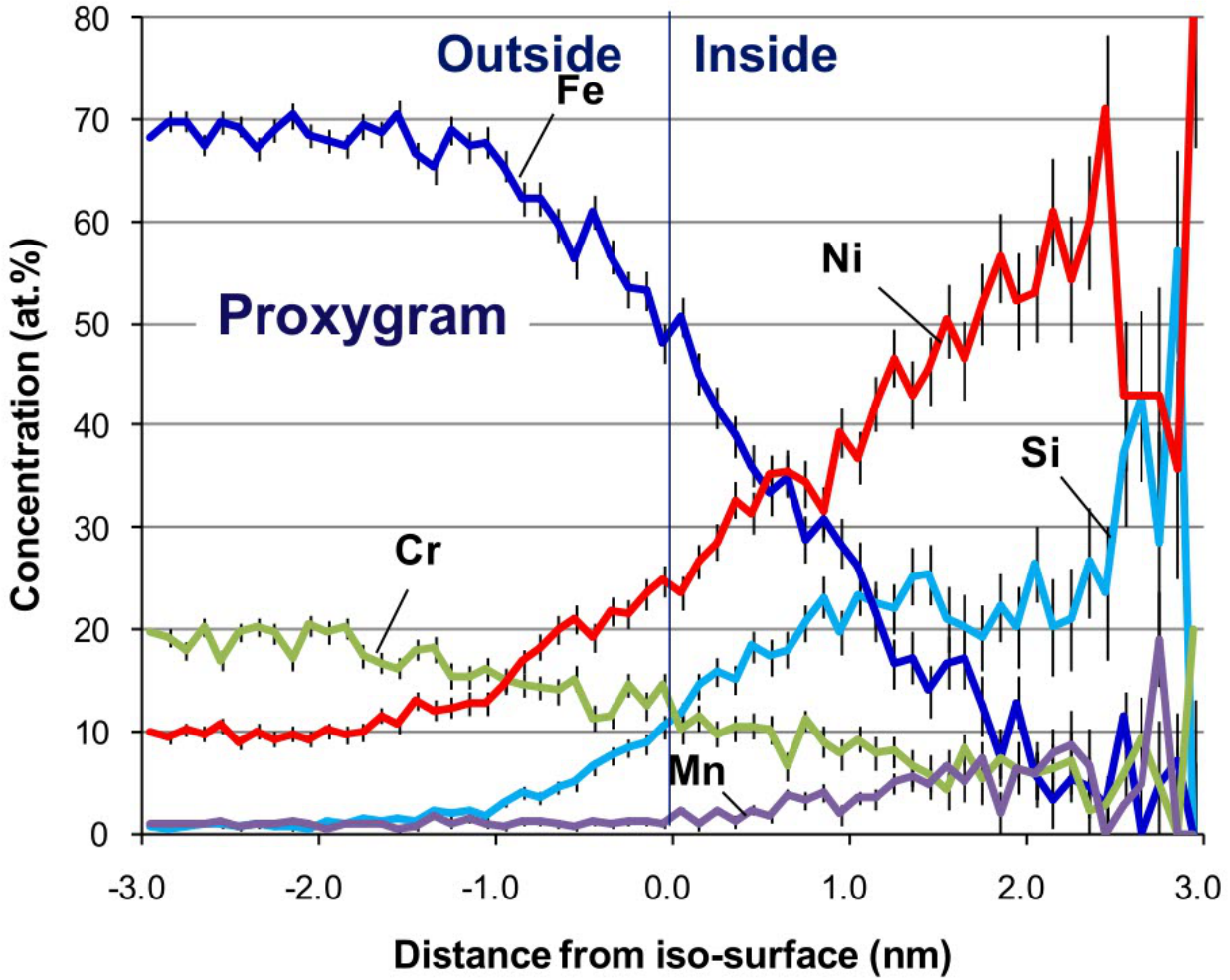
3.6dpa 5.9dpa 7.7dpa 13dpa

Damage (dpa)	3.6	5.9	7.7	13
Volume fraction	3.4%	7.1%	5.8%	19%

- Large increase in volume fraction is observed at 13 dpa.
- The shape of bounded regions is not spherical nor separated.

Chemical composition of Ni/Si feature in 304L

13dpa

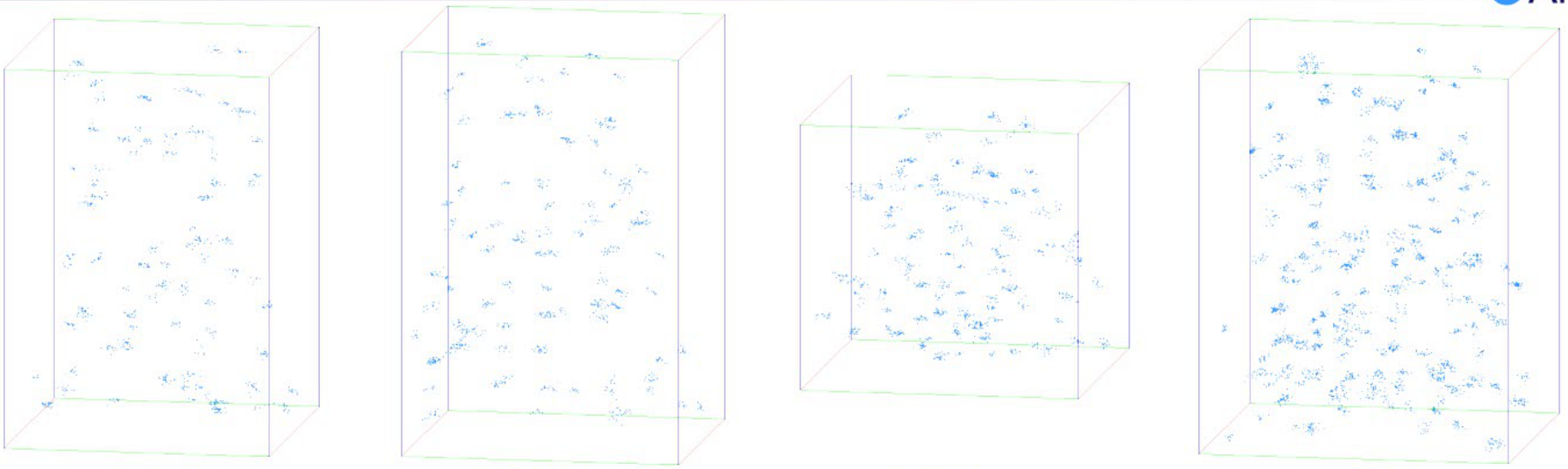


10at% Si isosurface

20~25 at.% Si, 50~60 at.% Ni, <10 at.% Fe&Cr near the center.

40 at.% Si, 40 at.% Ni, 10 at.% Mn <10 at.% Fe&Cr at the center.

Al enriched clusters in 304L SS



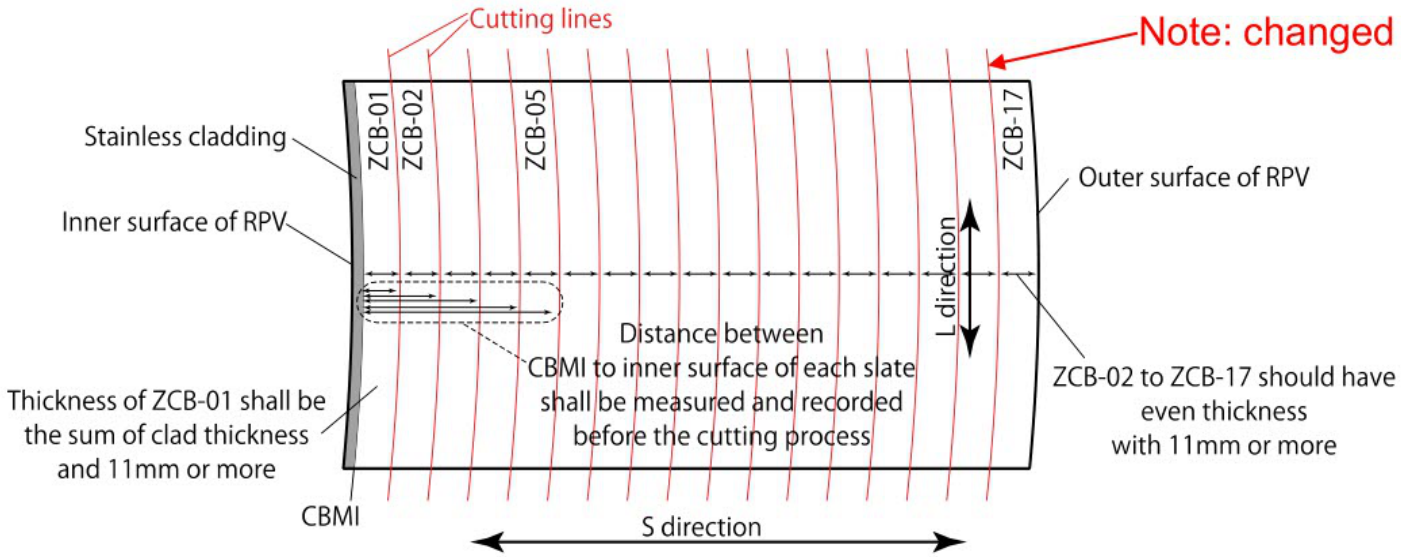
Damage (dpa)	3.6	5.9	7.7	13
Number density (m^{-3})	4.1×10^{23}	3.6×10^{23}	5.8×10^{23}	5.8×10^{23}

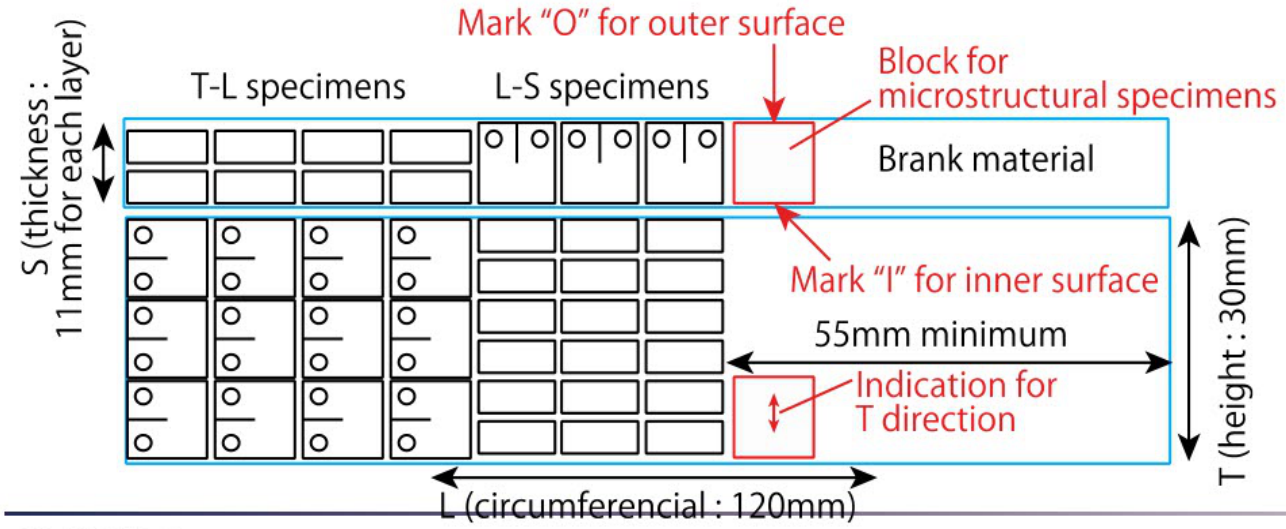
- Cluster diameter is >3nm.
- Enrichment factors of Al and Cu ***impurities*** are 50~100 and 4~5, respectively, although the amount of Al and Cu is small.
- Number density does not change very much with dose.

National Research Project (2015 to 2018)

- Collaboration with ORNL (LWRS)
- Harvested RPV steel from Zion
  - Evaluation of through-wall attenuation of Reactor Pressure Vessel embrittlement.
  - Mini-CT master curve fracture toughness, hardness, APT
- US PWR Ginna BFB material
  - Characterization of microstructure of irradiated stainless steels.
  - APT analysis

Cutting scheme for Zion unit 1





24 specimens
X
2 orientations
X
17 layers
↓
816 specimens

Summary

- For RPV surveillance materials, comparisons between the surveillance coupons and the actual vessel materials are important to demonstrate the adequacy of surveillance program.

- Materials harvested from actual vessels show the actual state of RPV materials.
  - Demonstration of large safety margin is expected

- No surveillance materials are available for core internal materials.
  - Expanding knowledge about irradiation effects on microstructure

Hamaoka unit-1 and R&D schedule

CHUBU Electric Power

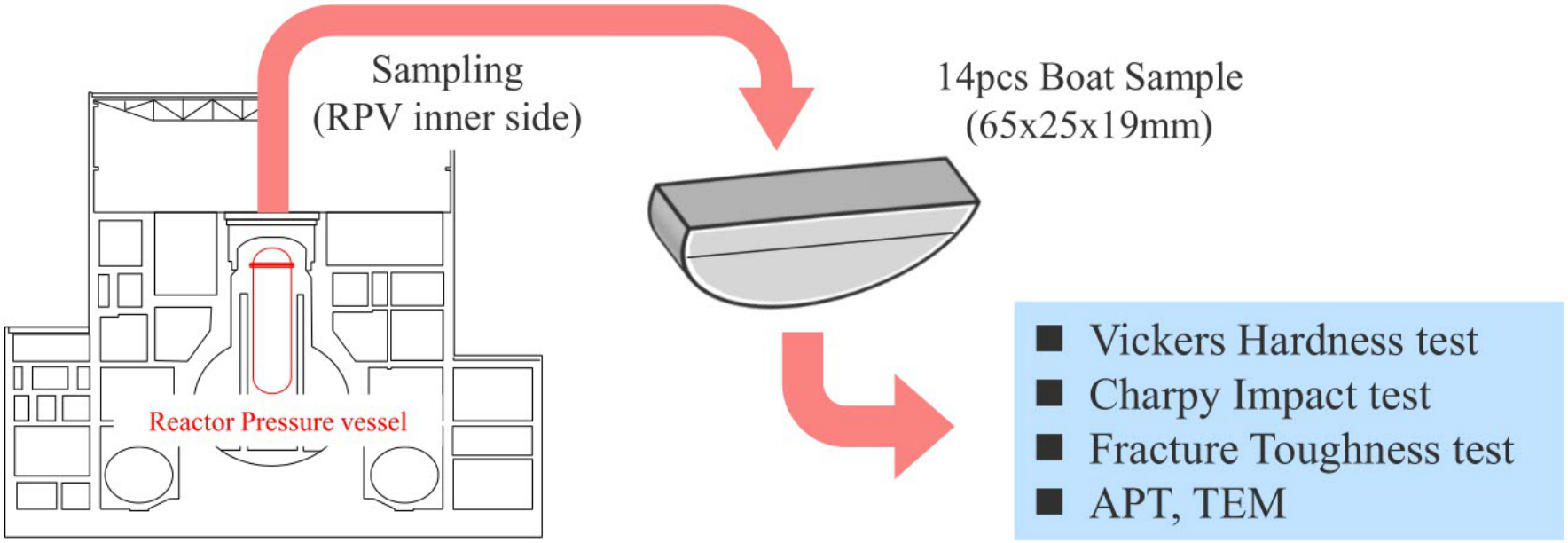
Specs of Hamaoka unit-1

Reactor Type	Boiling Water Reactor (BWR-4)
Power Output	540MW
Operation start / end	March 1976 / January 2009

Schedule of Hamaoka R&D (Fiscal Year)

	2014	2015	2016	2017	2018
Reactor Pressure Vessel		Boat Sampling	Sample Transportation	Examinations (actual & archive materials)	
Concrete Structures			Concrete Core Sampling	Examinations and Analysis	

Research plan (Reactor Pressure Vessel)



Objectives of Hamaoka RPV investigation :

✓ To characterize the inner cladding HAZ of base metal by
- Mechanical properties (Hv, ΔDBTT, K, etc.)
- Microstructure (Cu enriched clusters, Interstitial loops, etc.)

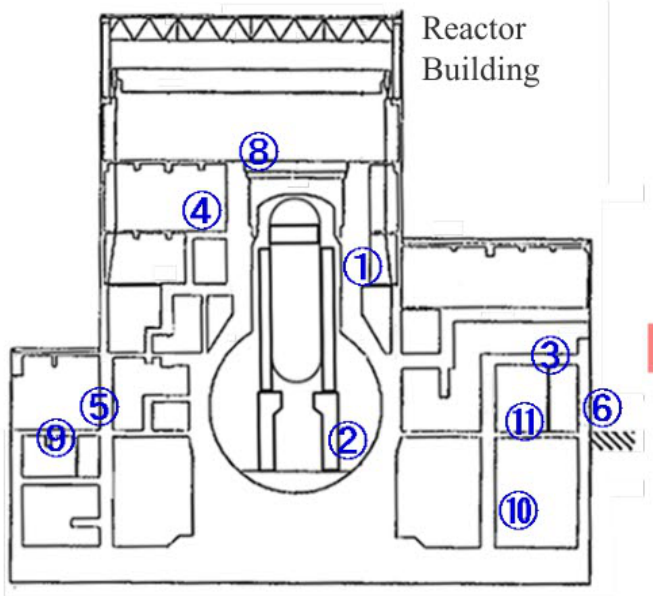
✓ To reconfirm the current maintenance methodology based on test results

Research plan (Concrete structures)

CHUBU Electric Power

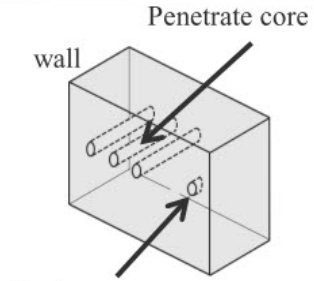
【Sampling sites】	
Expected radiation effect	① PCV Side Wall
	② RPV Pedestal
	③ Main Steam Tunnel
	④ Spent Fuel Pool
	⑤ Inner Wall
	⑥ Outer Wall
	⑦ Base Matt
	⑧ RPV Well
	⑨ Floor Slab
	⑩ Inner Wall
	⑪ Construction Joint

①②⑤: Already cored



◯ Locations of core sampling （Example）

Sampling from the various locations of the R/B (more than 40 sites)



Examination items

- Strength/Toughness
- Nominal density
- Water volume/TG-DTA
- SEM
- XRD
- Ultrasonic pulse velocity
- Carbonation depth
- Measure for ASR etc.

Performing various examinations

Objective of Hamaoka concrete investigation：

✓ To propose new soundness evaluation methods
- Formulation of concrete database
- Validation of non destructive examination
- Numerical Analysis Methods