Official Transcript of Proceedings

NUCLEAR REGULATORY COMMISSION

Title: Advisory Committee on Reactor Safeguards Fuels, Materials, and Structures Subcommittee

Docket Number: (n/a)

Location: teleconference

Date: Wednesday, March 22, 2023

Work Order No.: NRC-2321 Pages 1-219

NEAL R. GROSS AND CO., INC.
Court Reporters and Transcribers
1716 14th Street, N.W.
Washington, D.C. 20009
(202) 234-4433

DISCLAIMER

UNITED STATES NUCLEAR REGULATORY COMMISSION'S
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

The contents of this transcript of the proceeding of the United States Nuclear Regulatory Commission Advisory Committee on Reactor Safeguards, as reported herein, is a record of the discussions recorded at the meeting.

This transcript has not been reviewed, corrected, and edited, and it may contain inaccuracies.

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

+ + + + +

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

+ + + + +

FUELS, MATERIALS, AND STRUCTURES SUBCOMMITTEE

+ + + + +

WEDNESDAY

MARCH 22, 2023

+ + + + +

The Subcommittee met via hybrid in-person and Video Teleconference, at 8:30 a.m. EDT, Ronald Ballinger, Chairman, presiding.

COMMITTEE MEMBERS:

RONALD G. BALLINGER, Chair

CHARLES H. BROWN, JR., Member

VICKI BIER, Member

GREGORY HALNON, Member

WALT KIRCHNER, Member

JOSE MARCH-LEUBA, Member

DAVID PETTI, Member

JOY L. REMPE, Member

ACRS CONSULTANT:

DENNIS BLEY

STEPHEN SCHULTZ

DESIGNATED FEDERAL OFFICIAL:

CHRISTOPHER BROWN

ALSO PRESENT:

KYLE AMBERGE, EPRI

JIM CIRILLI, EPRI

HELEN COTHRON, EPRI

THOMAS DASHIELL, ACRS

GREG FREDERICK, EPRI

BOB GRIZZI, EPRI

BOB McGILL, EPRI

NATHAN PALM, EPRI

DAVID RUDLAND, NRR

JEAN SMITH, EPRI

RANDY STARK, EPRI

JOHN WISE, NRR

C-O-N-T-E-N-T-S

P-R-O-C-E-E-D-I-N-G-S

8:34 a.m.

CHAIR BALLINGER: Okay. The meeting will now come to some sort of order. There is one thing. This is a meeting of the Fuels, Materials, and Structures Subcommittee of the Advisory Committee on Reactor Safeguards. I'm Ron Ballinger, Chairman of today's Subcommittee meeting.

ACRS members present are Jose March-Leuba, Dave Petti, Joy Rempe, Vicki Bier, Greg Halnon, and -- I can't really tell -- Charlie Brown, Walt Kirchner. And if I've missed somebody, please -- I apologize in advance. Our consultant, Dennis Bley, is here -- well, is online or potentially online. And Stephen Schultz is here. And that's, I think, the list. Chris Brown of the ACRS staff is the Designated Federal Official for this meeting.

During today's meeting, the Subcommittee will receive materials reliability issues and information update on EPRI. And I might say that I believe that we are privileged that EPRI agreed to come and talk with us. This is the first of three meetings where, in effect, we will probably get what I would call a re-baselining of what's going on in the materials area, which I think would be very valuable, or will be very valuable, in the long run for the Subcommittee and the full Committee as a whole.

The Subcommittee will hear presentations by and hold discussions with EPRI and other interested persons, I think, regarding this matter. This meeting is open to the public. An announcement has been made regarding a potential issue we have with respect to presentations and participation and the like. Hopefully, it'll get solved by the end of the presentations.

The rules for participation in all ACRS meetings were announced in the Federal Register on June the 13th, 2019. The U.S. NRC public website provides the ACRS charter, bylaws, agendas, letter reports, and full transcripts of all full and Subcommittee meetings, including the slides. The agenda for this meeting were posted there along with the MS Teams link. We have received no written statements or requests to make an oral statement from the public.

The Subcommittee, again, will gather information, analyze relevant issues and facts, and formulate proposed positions and actions as appropriate for deliberation by the full Committee. A transcript of the meeting is being kept and will be made available. Today's meeting is being held in person and over Microsoft Teams. There is also a telephone bridge line and an MS Teams link, I think, allowing participation of the public.

When addressing the Subcommittee, the participants should first identify themselves and speak with sufficient clarity and volume so that they may be readily heard. When not speaking, we request that participants mute your computer microphone or phone by pressing star-6.

Again, this is the first of three meetings with EPRI. The next meeting will be on May the 18th. I think Chris has mentioned to Jim and others regarding the issues related to lunch. There's usually a place downstairs with a little mini food court kind of thing, but it is not operating today. So we thought about reserving a table at McDonald's, but they wouldn't accept it. But anyway, at lunchtime, we'll break for an hour and a half at lunch. The agenda calls for an hour, but we'll take an hour and a half.

We'll now proceed with the meeting. And, Randy, are you going to say something?

MR. STARK: Yeah. Just a couple quick introductory words. I have the mic on okay? Okay.

CHAIR BALLINGER: Okay. Wait. Why can't I hear? Okay.

MR. STARK: My name is Randy Stark. I'm the Director of Materials at EPRI. Just very quickly, I know you've worked with EPRI many years, but EPRI is a nonprofit, independent R&D organization with a mission to advance safe, reliable, affordable, and clean energy. We have a mission to be collaborative, and so we work very closely with our utilities and vendors and labs and such to advance R&D.

The team that's here today is here to talk about primary materials and light-water reactors. And I'll just make a couple quick points. First is that EPRI is a global company. We actually have more members outside the U.S. now than we have inside the U.S., so our portfolio of products is informed by our global communities. A lot of the work that we're doing in light-water reactors has touch points across the world.

The other point I'll make is we're sort of, right now, embarking on starting to work on non-light-water reactors and other advanced reactors. All of the presentations you're going to hear today are really focused on the existing fleet. But probably the next time we talk, we'll probably have some work that we're doing on advanced reactors as well.

And with that, I'm going to turn it over. I think each person in the room here will have an opportunity to talk about the areas that they're working in. So I'll have them introduce themselves when they go to present.

With that, I'm going to turn it over to Jim Cirilli.

MEMBER REMPE: Question. Do you mind real quick? When I was looking through this and listening to your talks this morning, I'm just curious how EPRI deals with export compliance. And has that changed like it has for folks in the DOE world where suddenly there's a lot more requirements that one has to consider?

MR. STARK: Well, we follow the same DOE export -- so we have members around the world that are cleared for export control. And every single one of our products goes through an evaluation of whether or not there's expert. So yeah. We --

MEMBER REMPE: Haven't noticed a difference? So people haven't complained? Like at the labs, people complained things are changing a lot.

MR. STARK: I have not seen it.

MEMBER REMPE: Okay. Just curious.

Thanks.

MR. STARK: I will say, right before I took this role, I was working as a Director of Fuel and Chemistry. And in the fuels, we have a lot of restricted reports that go through a lot more -- probably have a lot more export issues or restricted reports in that area than we do in the areas that we're going to talk about today.

MEMBER REMPE: Okay. Thank you.

MR. STARK: Yep.

CHAIR BALLINGER: Okay. Are you up first, Jim?

MR. CIRILLI: Yeah, Ron. Yes. Can you hear me okay?

CHAIR BALLINGER: I can hear you fine. It does seem a little different in the room with the microphone, but anyway, I think we're okay.

(Simultaneous speaking.)

MEMBER REMPE: Maybe this isn't working today, too.

CHAIR BALLINGER: Yeah. I have some troubles.

MEMBER REMPE: Try again.

MR. CIRILLI: Okay.

CHAIR BALLINGER: Yeah. It's mute.

MR. CIRILLI: All right.

CHAIR BALLINGER: But we can hear you, so --

MR. CIRILLI: Okay. Thanks.

(Simultaneous speaking.)

MR. CIRILLI: Just a little introduction. My name is Jim Cirilli. I've been with EPRI about a year and four months now. Prior to EPRI, I was with Exelon, now Constellation. And overall, about 40 years in the commercial nuclear power industry, all of which was in the materials degradation management area, engineering programs, at the utility level.

We're changing up the order just for the first two presentations because I think NEI 03-08, the Materials Initiative, to some degree sets the -- or establishes the -- baseline for a lot of the work that the materials programs are now and have been performing and you'll hear about today.

So, with that, let me just kind of talk about the underlying premise and the challenge that the utilities were facing some years ago. And I think we all understand that the integrity of the primary system materials is vital or critical to the reliability of our nuclear power plants. And we recognize they operate in harsh environments, and we don't always or haven't always understood the complexity of the degradation of mechanisms as these materials age.

So our routine surveillances or inspections were good at identifying and mitigating some of these attributes. However, the challenge was for the industry to get in front of materials degradation issues so that we identify them before they identify us in the form of a failure. That was the ultimate challenge back in the early 2000s.

So a little bit of history here. In the late 1990s and early 2000s, the BWRs were managing intergranular stress corrosion cracking of the reactor internals through the BWR Vessel and Internals Program and in the piping systems through VIP-75 and Generic Letter 88-01.

The PWRs, however, were experiencing significant materials degradation issues during that time. And there's four rather significant examples shown in pictures to the right on the slide. But the impact was very significant. The direct costs of unplanned repairs and replacements was very, very high. And then we had the cost for replacement power because we had some extended outages and forced outages that were required to deal with these issues.

And then the other aspects of this -- increased personnel dose and what I would term decreased regulatory margins because the NRC involvement ramped up as a result of this as well. And for any of us who have experienced these directly, the quality of life went down quite a bit.

So, again, on the right are four of the more significant examples of what the PWRs were experiencing in the form of materials degradation.

MEMBER HALNON: I had two out of the four, by the way.

MR. CIRILLI: So you mean out of the plants. So the quality of life thing hits you directly, right?

So how did the industry respond? Well, the NEI Executive Committee directed the utility executives to do something about this and develop a strategy, again, to get in front of these issues. And there were a couple of groups formed. One was an executive-level committee, and the other was a materials assessment working group that essentially performed self-assessment of all the materials programs at the time.

And you can see that we looked at the primary pressure boundary components on both the Bs and the Ps, materials issues related to fuels, nondestructive examination, chemistry and corrosion control programs. I won't go into detail about the work that that Committee did, but I'll just jump ahead to the end result. And that was NEI 03-08, the guideline for management of materials issues.

And at the time, the Chief Nuclear Officers of all the utilities that formed the NSIAC -- Nuclear Strategic Issues Advisory Committee -- signed this policy and agreed to commit to it. And it was treated as a regulatory commitment, and it still is today.

The initiative provides for -- and this is very important -- proactive management of these materials' aging issues. Another key aspect of this was coordination amongst the various materials issue programs. And that's not just within EPRI. That included the PWR Owners Group Materials Subcommittee.

The executives also pumped a significant amount of money into these programs in 2003, and that budgeting process still exists today. So we have a stream of funds to address and deal with these degradation management programs.

I'll talk a little bit more about this later, but issuance of industry guidelines -- one of the requirements is consistent and timely implementation of these guidelines. So not one plant or utility could decide to implement a guideline whenever they felt it was appropriate for them. The industry issued program and, as an industry community, established the appropriate implementation timing for certain guidelines.

And then, like everything else we do in our industry, we established an oversight process. And INPO is a key part of the oversight that's performed for these materials issue programs.

NEI 03-08 is currently on Revision 4. The most recent revision is really administrative in nature and reflects some changes to the names of the different material programs.

Any questions thus far on 03-08, how we got here? I think it's pretty straightforward. We're probably familiar with it.

MEMBER BIER: Excuse me. I hope this is just a clarification question. But when you said the individual utilities cannot decide for themselves when to adopt particular guidelines, you mean that they couldn't act ahead of the rest of the industry if they choose to? Or what exactly does that mean?

MR. CIRILLI: Great question. No, I did

not intend to imply that. It's just the opposite. If an issue program said this guideline needs to be implemented within the next two years, that's the implementation requirement. If a utility wanted to implement it or could implement it within six months, they could do that. Yeah. Thanks. Thanks for the question.

The scope of NEI 03-08 includes reactor internals, primary system pressure boundary components, and again, the related NDE programs, chemistry and corrosion control programs. And the programs that are directly referenced in NEI 03-08 are listed there. And with the exception of the PWR Materials Subcommittee, we're all represented here.

Now, a program that doesn't show up on that list, it does not mean they don't have some play or some participation aspect of NEI 03-08. The International Materials Research Organization performs research that supports some of the work done by these programs, and the same with the WRTC, the welding folks.

So the programs listed here on this slide are just those that are directly referenced in 03-08 and have direct applicability to the materials initiative. But it does not exclude other programs.

There are support functions.

Expectations -- and I think the industry has done a very good job of maintaining and complying with these expectations. When the 03-08 was first issued, utilities were required to develop a materials degradation management program, and they maintain that program to this day.

And that's an overarching program that -- I'll refer to it as an umbrella-type program that beneath it includes all the other programs, materials degradation programs, for that particular utility, whether it be BWR vessel internals, BWR pipe cracking, boric acid corrosion control, steam generator management, et cetera.

So it's a governing type of program that each utility has developed and maintained, and it was a requirement within NEI 03-08 to ensure that utilities had an overarching -- a holistic, for -- use another term -- program for the materials degradation management.

Again, regarding implementation, there are requirements for implementing the guidance step that's being issued, or has been issued and will be issued, under the NEI 03-08 program. And there are different levels of implementation: mandatory, needed, and good practice. And without getting into the details -- but they each carry certain requirements for each utility relative to implementing that guidance, and it has to do with the safety significance of that guidance into that issue, particular issue.

MEMBER HALNON: Jim, with the changeover of executives, always, it seems like it's a very fluid event. Is there any established norm for new executives to sit in front of you or any of the -- any else, like NEI, or do we just worry -- let it be --

(Simultaneous speaking.)

MR. CIRILLI: No, that's another good question. Some of that's addressed in the subsequent slide. But we periodically -- I don't want to call it training, but have a review session on NEI 03-08 for new executives. The last one was just before Robin Dial retired.

But that's a good question because there is, as we know, a rotation of utility executives. And we have regular meetings and phone calls to help facilitate the knowledge transfer.

MEMBER HALNON: Because compliance with this is based on good faith that I understand, and I want to continue on. But the new generation, as they're not going to be part of this V.C.

Summer/Davis-Besse -- it'll just be news stories in the past.

MR. CIRILLI: Yes. And that's something EPRI has taken on, that knowledge transfer, continue the knowledge base of NEI03-08.

Utilities also are required to implement the guidance, like I said, and participate in issue programs. So they're not just sitting on the side waiting for guidance to be issued. They are active participants and engaged in the issue programs, whether it be through meetings, et cetera. So there is active participation on the part of utilities in all these programs.

And another key aspect of this is communicating operating experience. And in that -- and again, on the subsequent slide -- we have an emergent issue protocol that's part of NEI 03-08 that is very important for communicating emergent operating experience discoveries during refueling outages.

So those are the four key utility responsibilities under the materials initiative. The issue programs, the materials issue programs, the EPRI programs, the NSR&D programs, again, we're responsible for identifying, prioritizing, and resolving these materials degradation issues. And Jean is going to give you a really good overview of how EPRI does just that.

The industry programs help communicate the OE across the industry. And when I say across the industry, I'm including the international plants as well. International OE is considered just as much and at the same level as domestic OE and vice versa. So --

CHAIR BALLINGER: So this is Ron Ballinger. So what you're saying is that the international members of EPRI now have signed onto 03-08?

MR. CIRILLI: No. I'm not saying that, Ron. The international members have not signed onto 03-08 necessarily. Some may be using it as a guidance document. However, OE that's experienced internationally -- we get that OE, and we follow our materials initiative guidance for evaluating that OE.

And you'll hear about two recent examples of OE. I'm sure you're interested in what the materials groups here in the U.S. are doing for evaluating that for applicability. Issue programs obviously develop the guidance, manage the regulatory interface in generic issues, and manage the process, which is the 03-08 initiative.

Any other questions on how we implement this?

MEMBER HALNON: Just one real quick one. I'm sorry.

MR. CIRILLI: Sure. No.

MEMBER HALNON: Is there any involvement with INPO in this?

MR. CIRILLI: Yeah. Absolutely. It's a great -- Greg, you're a great frontman. So, again, INPO is part of the oversight process. And their part in this is they perform the material review visits of sites, and they take an industry diverse team of utility and EPRI and sometimes vendor members, put a team together, visit a site, spend about a week, and review all the materials degradation management programs.

And those are the material review visits. And each site is on the five-year cycle. So, if Plant X is reviewed in 2020, their next materials review visit will come up in five years from there.

CHAIR BALLINGER: On the international side, is WANO involved?

MR. CIRILLI: Not directly in the materials review visits, but there has been some, I'll say, interaction between a WANO visit -- maybe for the boric acid program, from my personal experience prior to being with EPRI -- where WANO my take on, say, a boric acid walk-down and boric acid program review and feed that information to the INPO Materials Review Team. But --

CHAIR BALLINGER: Because I'm getting outside my area, but it's my understanding that plants have a WANO rating. And if they get a bad WANO rating, that's not a good thing.

MR. CIRILLI: Correct.

CHAIR BALLINGER: Can that be influenced by these materials visits?

MR. CIRILLI: Yeah. Yes.

MEMBER HALNON: The WANO visit is similar to an INPO visit. So you're going to have the same people involved, basically, since it's some international stuff.

CHAIR BALLINGER: Thanks.

MR. SCHULTZ: Jim?

MR. CIRILLI: Yeah.

MR. SCHULTZ: Steve Schultz. A question. You talked about some international programs that are involved here. With regard to other interfaces, what is the EPRI interface and the program interface with national laboratory activities?

MR. CIRILLI: Jean, I think you're best on our interaction with the national labs.

MS. SMITH: Right. So we collaborate with the Department of Energy and their labs in several research projects and also in some collaborative group efforts, say the NEA FIDES program on fuels and materials. We use the national labs for special services programs, SSPs, where they do work directly for EPRI and not in a co-funded way. We pay them to do research for us at EPRI. We also collaborate with NRC research on projects with DOE.

MR. SCHULTZ: Thank you.

MR. CIRILLI: Thanks, Jean.

I'm taking up too much time. I thought I would be quick, but I'm running on here. Just a couple things to highlight on this slide.

Accomplishments -- strategic plans. Strategic plans help us get in front of these materials issues. And strategic plans are developed by each of these individual materials programs, whether that's the VIP, MRP, SJNP, et cetera. So it's an important aspect of this materials initiative.

We have a process for deviations. If a particular utility or plant wants to deviate from guidance, there's a process for that. Those deviations are reviewed, and any deviation is communicated to the NRC. So, again, this is treated as a regulatory commitment. Deviations are not taken lightly. The challenge by peer utilities and the industry groups on any single deviation are pretty substantial.

So, to the point of the turnover in utility executives, the utility executives, from my experience, have been pretty good in challenging their peers on any deviation. And I'll say a deviation for a matter of convenience, like scheduling -- it doesn't fit in your schedule -- is completely unacceptable.

And this shows the structure of the materials organization with the executive committees and rolling down on the PWR side with the PMMP Executive Committee and the BWR side on the right there.

Part of the continuing communication process is on the far right with the Materials Aging Program coordination. We have bimonthly calls with the utility leadership, utility executive leadership. The utility leadership for each of those Committees you see shown on the slide, and the EPRI program managers as well. And we discuss material program updates, any significant OE, and again, it's a bimonthly call to keep the communications going.

And that's it. Thanks. Any other questions, now that I've cut into Jean's time?

CHAIR BALLINGER: Okay. Thanks. What we're going to try to do is to rectify a problem which we're having, and we're going to try to reboot our system between presentations. So we'll take a few minutes or whatever it takes to find out whether we're successful or whether we gotta revert back.

(Whereupon, the above-entitled matter went off the record at 9:02 a.m. and resumed at 9:07 a.m.)

CHAIR BALLINGER: Okay. So we're back to zero. But there's a question from the audience that -- I don't know how you do it.

MR. WISE: I can just stand here.

CHAIR BALLINGER: Okay.

MR. WISE: Hi. John Wise, NRC staff. Just a quick following question on your presentation. A few years back, a few utilities left NEI. Does that have any implications with respect to following NEI 03-08 and how that works?

MR. CIRILLI: They still are part of the Materials Initiative. Yeah. That's a requirement.

MEMBER REMPE: A requirement by whom?

MR. CIRILLI: It's an NRC commitment that they've made --

MEMBER REMPE: Okay.

MR. CIRILLI: -- as a facility. So --

MEMBER REMPE: Just trying to make sure. Thank you.

CHAIR BALLINGER: Okay. We're still in kind of a situation where people can't really call in, if you will. But just speak loudly because that microphone works if we're sitting there in the other room, but we're not.

MS. SMITH: We'll leave it on anyway. So good morning. My name is Jean Smith. I'm the Program Manager for International Materials Research. I've been with EPRI almost 13 years now. Prior to that, I came from a U.S. utility. Before that, I was in the petroleum industry.

By means of introduction, I have a PhD and master's degree in materials engineering from Rensselaer Polytechnic Institute and a bachelor's degree in metallurgical engineering from Missouri University of Science and Technology. I'm a licensed professional engineer in the state of Illinois.

An overview of what we're going to talk about today, and it's our EPRI Materials Aging Management Cycle, two of our most important documents that we work from, which are the Materials Degradation Matrix and the issue management tables. We'll introduce the process that we're using for developing an MDM for advanced non-light-water reactors and share with you our next steps.

So we heard from Jim a lot about operating experience. The first part of our ongoing Materials Aging Management Cycle deals with the collection of operating experience. Our EPRI subject-matter experts collect data from field reports and inspection results not just here in the U.S. but worldwide.

We also use operating experience and inspection results to assess the efficacy of corrective actions, for example, pinging or the addition of zinc in PWRs or as a mitigated approach, or other repairs and replacements.

Simultaneously, we are also constantly reviewing research results either from our own EPRI programs or from the technical literature, attendance at conferences, and so on. The combination of this information on operating experience and research results inform our Materials Degradation Matrix, and we'll go into more details in the next few slides on that.

The Materials Degradation Matrix really

identifies degradation concerns for different materials in different reactor types, but it doesn't do anything to prioritize or tell us the specific problem that we're trying to address. That occurs in the next step, where we review the knowledge gaps from our Materials Degradation Matrix and put them in the context of particular or specific reactor components or reactor concerns.

In this particular step, we work very closely with our utility members to prioritize the gaps that are in our issue management tables. And you have, currently, issue management tables that are specific to BWRs, PWRs, and VVERs.

Through the NEI 03-08 program, we, EPRI, in our Materials Department, in our own metrics that we maintain for the Materials Department, we are obligated to provide funding for and show advancement to 90 percent of the high-priority gaps that have been identified specifically in the BWR and PWR issue management tables.

So we conduct research on representative materials, we perform simulations, and we develop models to address the high-priority assessment in degradation gaps from the issue management tables. The results that we get from our research are used to calibrate our models and improve the accuracy and robustness of our databases.

So the more robust our data is that goes into our models, the more data that we have to benchmark our models, the more accurately we are able to calibrate our models and be mindful of the conservatism that we've built into our models and inform our aging management strategies.

One of the biggest outcomes of our aging management strategies is inspections. So the more accurate our models are, the more we can optimize our inspections either in terms of frequency or in terms of scope. And then that takes us back to the beginning, where we're collecting the results from our inspections and collecting results from operating experience and research.

CHAIR BALLINGER: This is Ron Ballinger. Are these issue management tables available to us?

MS. SMITH: Yes, sir. And the product IDs are shown on this slide, and also, on the very last slide, it will show you how to obtain them from epri.com.

CHAIR BALLINGER: Thank you.

MEMBER KIRCHNER: Jean, this is Walt Kirchner. Could you just give an example of what you're doing in calibrating models? Are you able to use them --

(Simultaneous speaking.)

MEMBER HALNON: Hey, Walt. Walt, stop for a second. I'm going to try to put your volume up. Hold on, because we're not listening to you. We can't hear you.

Try and ask your question, Walt.

MEMBER KIRCHNER: Oh. Thank you, Greg.

Jean, in calibrating models --

(Simultaneous speaking.)

MEMBER HALNON: Yeah, Walt. Go ahead and ask your question.

Now he's not talking.

(Off-microphone comment.)

MEMBER HALNON: Maybe it's my speaker.

CHAIR BALLINGER: Can you just translate? Can he --

(Off-microphone comment.)

MEMBER HALNON: Yeah. They're not plugged in anymore.

MEMBER KIRCHNER: Shall I try again, Greg?

MEMBER HALNON: Walt, you have to ask your question over the chat line.

MEMBER KIRCHNER: Okay.

(Off-microphone comments.)

MEMBER HALNON: I haven't seen it yet.

MS. SMITH: Feel free to interrupt when it comes through.

MEMBER HALNON: I will. I've lost my audio now, too.

MR. SCHULTZ: Jean, Steve Shultz. Just a question on that previous slide. Interested that your last bullet is that it leads to optimized inspection requirements. And so first time -- or generally, you hear about optimized programs with EPRI. But now you're interfacing in determining requirements associated with the inspection and so forth. I presume there's interaction with the NRC in that regard?

MS. SMITH: So, by optimized inspection -- for example, for the PWRs in the document MRP-227, the Inspection and Evaluation Guidelines, the models that we've developed help us inform the requirements that are included in, say, MRP-227 with respect to reactor internals inspections.

So optimized inspection requirements, maybe, is just wording to indicate that we take our models, and we include them in the documents, in the guidance documents, that we produce for the issue programs.

MR. SCHULTZ: With the NRC commitments that are established by the owners' groups. Then what you're saying here is that the requirements are continuously changing based upon the information learned from the programs moving forward?

MS. SMITH: They do change. But I will say that the world of, in particular, irradiated materials research isn't very dynamic. Things aren't changing very quickly. Probably, our inspection requirements change more on the basis of operating experience than our research results in the calibration of the models.

MR. SCHULTZ: I see. Good answer. Thank you.

MS. SMITH: Mm-hmm.

CHAIR BALLINGER: So it's consistent with Section 11, right? The inspection requirements --

MS. SMITH: Well, these are inspection requirements based on EPRI guidance documents, not ASME documents.

MEMBER HALNON: Well, Walter asked the -- on the calibrating models whether these are used in a predictive manner.

MS. SMITH: I'm thinking more specifically of some of our internal models that are based on -- not predictive in the risk-informed sort of way, but the prediction of when and where degradation might occur, so which components might be susceptible to a specific type of degradation and at what point in operation.

MEMBER HALNON: Okay.

Walt, did that answer your question?

MS. SMITH: Nathan would like to respond on --

(Simultaneous speaking.)

MR. PALM: -- some examples in my presentation that'll be next showing how we collected data and evaluate the data. And I'll talk a little bit about how trying to apply that to -- to what have you. So that might be helpful.

CHAIR BALLINGER: You're not on speaker.

MEMBER REMPE: For the court reporter, you need to say your name.

MR. PALM: Oh. I'm Nathan Palm. I'm the BWRVIP Program Manager.

MEMBER REMPE: Thank you.

CHAIR BALLINGER: Okay.

MS. SMITH: So the Materials Degradation Matrix summarizes the state of industry knowledge regarding the degradation mechanisms and also related research activities. The MDM was first released in 2004 but was not in the same format that we see today.

In 2008, we adopted the format that we use now and adapted a multilevel structure that is separate tables for each of the reactor types. In the second revision, we considered long-term operations. The third revision included the addition of CANDU reactors. And our most recent revision, Revision 4, included the addition of tables for the VVER fleet.

All of the degradation mechanisms are defined in the MDM for normal operating conditions. And you can see in the table on the right the example of -- it's Table 4-1 from the MDM, and it's on PWR primary pressure boundary materials.

All of the tables are formatted similarly in that the first column is for a material, and then the cells going across the table are for the various degradation modes. These degradation modes are common across the tables for the different reactor types and the different component classes.

Within the tables, you'll see coloring. A green square means that the combination of that material and that degradation mechanism is well understood, and no additional research or development is needed. If the square is colored yellow, it means that we have sufficient R&D in progress to currently address the gap in a reasonable time frame.

And orange cell indicates that we either don't have research going on at the moment or it's not sufficient to be able to address the gap in a reasonable time. A blue square indicates insufficient data exists to establish the degradation mode applicability. So we're not fully clear if, say, for example, that degradation mechanism is applicable to that material, say, in this example for PWR, primary pressure boundary.

Each of the cells also has a hyperlink in it, so when you click on the hyperlink, it takes you to a next page with the explanatory notes.

MR. SCHULTZ: Jean?

MS. SMITH: Yes, sir.

MR. SCHULTZ: Just to comment, I'm surprised there's not more yellow here. We've got green where things are well understood, no R&D necessary. And then a bunch of the rest is either orange or blue where we've got insufficient R&D or insufficient data. Just a comment, and your reaction to it?

MS. SMITH: If I go to the next slide, I

can find more yellow for you.

MR. SCHULTZ: Perfect. Thank you.

MS. SMITH: This is an example of Table 4-3, which is PWR steam generator components. It's really just specific to the material class. So steam generators versus RPBs and what we do and don't know. We can find all the colors if we look.

MR. SCHULTZ: Understood. Thank you.

MS. SMITH: Mm-hmm.

So, within each cell, there's first a letter, the letter Y, and a question mark or a Not Applicable, which tells us whether or not the degradation mechanism applies to that particular combination of material and degradation mode.

The color, as we just discussed, is the background of each cell. And then there's an explanatory note hyperlink. In this example, the hyperlink is P as in papa, which is for PWR. The number 1 is meant to represent Table Number 1 for PWRs. The 3 is the third column, and the C, the Charlie, is the row. So everything feeds back.

Within the explanatory notes, you'll see that in some cases, the same note applies to two different squares. And there's information about the degradation mechanism, the applicability to that particular component, and then references, both internal EPRI references and other references as well.

So, from the Materials Degradation Matrix, we look at all of the squares that are applicable, so had the letter Y in it, and we take a look and developed these issue management tables that proactively identify and prioritize the various states of material degradation and provide the capability to manage the R&D gaps.

So our R&D gaps that are identified in the issue management tables fall into five different categories. So we have degradation mechanism gaps. These are closely aligned with the orange squares in the MDM, and it indicates that we need more research to understand the degradation mechanism itself.

Assessment gaps imply that either the mechanism is understood -- we understand the degradation mechanism -- or perhaps, in some cases, it's not important that we fully understand the degradation mechanism on, say, the material green level. Rather, it's more important that we understand the impact or the need to manage that particular degradation.

Mitigation gaps suggest that R&D is needed to either develop or to demonstrate a mitigation technology. Similarly, inspection and evaluation gaps suggest that inspection guidance, NDE qualification, or development is needed. And then repair or replacement gaps indicate that development or verification of a repair technique is needed.

The example shown on the right is from the PWR issue management table, and it's a listing of the degradation mechanism gaps with the mechanism -- the gap highlighted is environmental effects on fracture. Again, there is an explanation of the issue related to environmental effects on fracture. It talks about some of the current research results and also describes the research that's required to close or fully address the gap.

In the right-hand margin, you'll see that there's a history of the prioritization of that particular gap with each revision of the issue management table. So, for example, this particular gap was considered a medium priority for the first three revisions of the PWR issue management tables. And in its current revision, it was downgraded to a low-priority gap.

The PWR and BWR issue management tables were initially released in 2007. They are revised periodically just after the revision of the MDM. In

2021, we issued VVER issue management tables, and we currently have CANDU issue management tables under revision.

You can see in the bottom left, in the plot, the number of open issue management table gaps by reactor type. In defense of the PWRs, PWR issue management tables also include the steam generator, so kind of a big component that sort of adds to the number of gaps that they have.

CHAIR BALLINGER: I'd like to ask what's probably an inappropriate question, but are the issue management tables for the VVERs more substantial than for the current fleet PWRs and BWRs?

MS. SMITH: More substantial --

CHAIR BALLINGER: In other words, are there more issues with VVERs than there are currently with our fleet here?

MS. SMITH: There are not.

CHAIR BALLINGER: There are not.

MS. SMITH: In fact, the blue bar shows they have, in fact, fewer gaps than the other reactor types.

CHAIR BALLINGER: Thank you.

MS. SMITH: For each reactor type, however, the assessment-type gaps are the most prevalent. And those are the types of gaps that really play into our aging management strategies. Understanding and recognizing degradation modes and how to manage or inspect or provide replacement plans for those types of degradation modes are the most common.

MEMBER REMPE: I want to follow up on Ron's question. Why are the VVERs not having as many issues? Because we recently had an interaction with some folks from Finland, and they identified that they were monitoring, and they identified some issues.

MS. SMITH: I think I can address this on the next slide, and I'll share why. So we currently have CANDU IMTs under development. And the approach that we're using to develop the CANDU IMTs is the same approach we used for developing the VVER IMTs.

So, with the VVER IMTs, we started with the PWR issue management tables. We, EPRI, met with a collection of materials experts from the various countries that own and operate VVERs as well as some independent experts from that VVER community. So we went through each and every one of the PWR issue management table gaps and said, is this something that pertained to a VVER? Yes or no? We compared research results from the PWR community with the VVER community.

We were able to close a number of PWR gaps for the VVERs. So, in other words, there were some open PWR gaps that were not applicable to the VVER gap world. But there were also some issues from the VVERs that were included that are not part of our PWR IMTs.

One example that I'll regret is that in the PWR issue management tables, base following is considered a low-priority gap, whereas for the VVERs, base following is considered a high-priority gap because of their operating temperatures. So there's a difference in the prioritization of some of the gaps that are identical between the PWRs and the VVERs.

MEMBER REMPE: Thank you.

MS. SMITH: Okay.

MEMBER REMPE: Is it that they got more proactive earlier on, too, or that they've been monitoring more?

MS. SMITH: I think it has more to do -- it was interesting, for example, when we brought these materials experts from these utilities together, that they hadn't previously done that. We do a lot of sharing across our utilities, both domestically, but within our international fleet, for PWRs and BWRs.

We had folks from the Ukraine, from

Finland, from Hungary, Czech Republic. They hadn't really sat together in a forum to exchange operating experience in the way that we brought them together to develop the issue management tables. They have some programs ongoing in the EU Horizon Program right now for long-term operations that's continuing to bring these organizations together to work collaboratively to address long-term operations.

I think maybe there are fewer gaps because of the way they chose to address, maybe, repair and replacement in particular, or inspection. There were things that they chose to just -- not necessarily include in the issue management tables, but rather continue to address with other programs.

MEMBER REMPE: Thank you.

MS. SMITH: So, in a similar way, we're developing CANDU IMTs, again, drawing from the experience of the PWRs with respect to the steam generators and secondary site components and piping into the primary heat transport system. There will be specific gaps related to CANDU fuel channels in the Calandria vessel, those components being specific to that design.

The experience that we have had with our Materials Degradation Matrix and our issue management tables is a process that we are now applying to our advanced non-light-water reactors. Prior to 2021, EPRI published a series of reports looking at material, property assessments, and data gaps for four different types of Gen IV or non-light-water reactors.

And those results were published in those reports that are shown along the top row. And they came together into the Advanced Reactor Materials Development Roadmap. And that particular roadmap talks about what our needs are with respect to extending ASME code property data, concerns with corrosion, and irradiation properties, and lays it out in a timeline of what needs to be addressed to help deploy these different reactor types.

EPRI is currently actively working to develop Materials Degradation Matrix for the advanced non-light-water reactors using a process and a format similar to our current light-water MDM. Once we have finished the MDM for the non-light-water reactors, we will take a look at developing issue management tables for each of the Gen IV reactor types.

So, to summarize, we currently have Revision 5 of the MDM underway. We have assembled our teams of experts for each of the reactor types, and we are updating the state of knowledge based on our operating experience and our research results. And we anticipate publication at the end of this year.

The CANDU IMT, as I mentioned, will be published later this year as well, with PWR and BWR IMT revisions taking place next year in 2024. And then the Revision 1 of the VVER IMTs will follow after the MDM Revision 5 is complete.

We're currently developing an advanced non-light-water reactor. And not to be left out, the light-water reactor, small modular reactors, or LWR SMRs, as we are calling them, will be informed by Revision 5 of the MDM in terms of materials and environments. And we will ultimately develop some reactor design tables for the light-water SMRs as well.

All of these documents can be found on epri.com using the product ID number -- that's the one that starts with 30020-something -- or if you're able to access the link in the handouts.

MR. SCHULTZ: Are you going to continue to integrate the results for the advanced reactor -- or the new reactors, I'll call them -- into one program? In other words, is that going to be Rev 6 as you go forward?

(Simultaneous speaking.)

MS. SMITH: We --

MR. SCHULTZ: -- interaction between what you have now and what you will have in the future?

MS. SMITH: We envision keeping the advanced non-light-water reactor MDM separate from our current MDM. There is the potential to incorporate light-water SMR into our current MDM.

But at the moment, we think it's cleaner to keep our current products -- leave them alone because they're products that, because they are publicly available, we know that researchers at the national labs here in the U.S. or researchers worldwide rely on that common format and have an expectation of the timing of the revisions and the revisions of the IMTs as well.

And we don't really want to get out of sync with that or wait for the non-light-water reactors or the SMRs.

MR. SCHULTZ: Good. Thank you.

MS. SMITH: Mm-hmm.

MR. CHEN: Hi, Jean. This is Frank Chen from the FES program. And when you showed the issue management table for different reactor types and compared them, I'm wondering if you have evaluated how the gaps being identified -- let's say in particular for PWR -- how that changes over the years.

MR. DASHIELL: Yeah. Frank, I think it was just you talking. We're unable to hear you in the room. If you can ask your question over the chat line or give me a thumbnail of the long question you had, I can try to translate it back.

MR. CHEN: Okay. I'll type it in chat.

MR. DASHIELL. Thank you.

He's going to type it in the chat.

MEMBER REMPE: Is Frank a member?

MS. SMITH: Well, if Frank's a member of the public, he's not allowed to ask.

MR. DASHIELL: Oh.

MS. SMITH: I don't know if he can ask this question.

MR. DASHIELL: I don't know if he's a member.

MEMBER REMPE: I think it's Frank Chen from Oak Ridge.

MS. SMITH: Is he somebody that's under contract to EPRI? So you need to tell --

MEMBER REMPE: Excuse me. This is the Chairman of ACRS. And when we ask for members to provide questions, we are doing this because of our unusual situation with the IT. If you're a member of the public who is not under contract to NRC or to EPRI, you need to wait till we open up the line for public comments. And we apologize, but that's the way this is run.

MR. CHEN: Okay, I apologize for that. I didn't know that. I'll just wait.

MR. DASHIELL: I passed your apology along.

MR. PALM: All right. Well, good morning. I'm Nathan Palm. I'm the program manager for the boiling water reactor vessel internals project. I've been in this role about three and a half years, and prior to being the program manager, I was a technical leader in the BWRVIP, so I've been with EPRI about ten years total and then in the nuclear industry working pretty much entirely in the materials-related area for 22 years.

So, I'm going to start by just giving a little bit of an intro on the BWRVIP program, you know, how it came to be, what it's about, what we try to do, and how it's structured.

And then I'm going to talk about five different technical areas, and I selected these just because they're things that I think are substantial that we're working on. There's nothing more magical to how I selected them than that, but, you know.

CHAIR BALLINGER: Good move.

MR. PALM: And hopefully they'd be of interest to you and I think they just, they kind of show, you know, areas where we're proactively trying to manage aging.

So, as far as the history of the BWRVIP, Jim touched on this a little bit in his presentation, but the BWR, we experienced IGSCC, intergranular stress corrosion cracking, in stainless steel piping in the 1980s and, you know, it was a really big issue and ultimately resulted in Generic Letter 8801.

And, you know, at that time, it was recognized, well, we have these same materials and same conditions in the reactor internals for the BWR, albeit we haven't seen the IGSCC there, but, you know, I think some people saw the writing on the wall.

And sure enough, you know, come 1993, 1994, we did have our first instances of IGSCC, you know, in the core shroud and, you know, that confirmed that, you know, we could be at the tip of the iceberg here.

And, you know, the utility execs at the time, you know, still had the history with IGSCC of piping kind of fresh in their minds and said we don't want to go through the same evolution we did with piping. We want to get ahead of that, and that's really what resulted in the formation of the BWRVIP and that occurred in mid-1994.

So, you know, this was all pre-NEI 03-08, but really kind of has some of the same motivations of NEI 03-08, and that is to proactively get ahead of the materials issues.

So, you know, the VIP wanted to develop these means to address the degradation, and manage the degradation, and also, you know, do it in a cost-effective manner.

You know, another objective was for the BWRVIP to serve as a focal point, you know, for interfacing with the NRC on BWR degradation issues, and we're here today, so I think that's kind of evidence of that.

And then another big thing was to be able to share information among members to obtain useful data from many sources and I think, you know, Jim and Jean kind of touched on that and I'll just say that, you know, when the VIP meets on --

The technical committees meet twice a year and one of the biggest things that we do is have a session focused around, you know, the sharing of OE and, you know, that's both our domestic and international members, you know, presenting that information. So, you know, in terms of --

MEMBER HALNON: Nathan, before you go on, just curiosity I guess, the VIP, you know, when these things first happened and turned into an industry crisis, you know, shroud cracking, oh, my goodness. The higher levels of the engineering and utility management are involved in those types of committees.

Over time, that tends to get pushed down to the lowest and probably even just a staff engineer maybe. Have you seen the executive report for the VIP stay pretty constant to where, you know, you're confident that those technical committees and the results of those are, you know, the commitments made are going to get assimilated?

MR. PALM: Yeah, I think so. I mean, you know, I'm not going to say that it's exactly the same as it was, you know, 30 years ago when this stuff was really fresh, but I think we still do have a very active and engaged executive committee.

MEMBER HALNON: Okay, so they have teeth. They can really --

MR. PALM: Yeah, yeah, and I'll touch on the organizational structure a little bit, but yeah, I mean, I feel confident that we have good leadership in place that, you know, is sensitive to still addressing the issues of today.

And, you know, I know one of the things I do each time we do get a new executive member is I take the time to sit down with them for an hour or two and walk them through, you know, what's the history of the program, why does it function or how does it function, you know, why does it exist and all of those things, so.

MEMBER HALNON: Okay, thanks.

MR. PALM: Sure. So, in terms of the membership of the VIP, we have all of the U.S. BWRs. U.S. utilities that operate BWRs are certainly members of the VIP, and internationally, we have almost all of the international utilities that have BWRs with two exceptions, well, Finland, and then there's two utilities in Japan that currently aren't members, but there are currently no operating BWRs in Japan, so our hope is that those Japanese utilities will join once they get units back online.

So, here is the organizational structure of the BWRVIP. We do have, you know, an executive committee that's really responsible for ultimately approving any NEI 03-08 guidance, you know, that we propose. They are also responsible for, you know, finally endorsing our kind of scope and budget on a yearly basis.

We have an executive oversight committee, and the way I describe that committee is it's just kind of a smaller, more nimble subset of the executive committee, but within that committee, we have some important roles where you'll see these executive sponsors.

So, you know, these are people that actually make a point of attending all of the technical committee meetings and, you know, making sure that they're really engaged in the technical work and then can be a conduit back to the rest of the executive committee, you know, regarding that technical work.

You know, beneath the executive committee, we have a research integration committee that takes, you know, all of the input from the technical committees and they develop kind of a recommended scope of work on a yearly basis that is then, you know, fed up to the executive committee ultimately for endorsement.

And then you see we have three technical committees, assessment, inspection, and mitigation, and I'll talk about what those committees are responsible for on the next slide, but the only other thing I'll just point out is we try to make sure that in each of these committees, you know, we have a good succession plan.

So, you'll see in some cases we have two vice chairs, but, you know, the idea is to just, if one of these people have to move onto something, some other commitment, we've got an immediate backup in place.

So, in terms of the responsibilities for the committees, so the assessment committee is really our biggest area and they're responsible for addressing what needs to be inspected, when it needs to be inspected, what are the options for inspection, and how to disposition observed degradation, and it's not stated on there, but they're also responsible for, you know, determining what research is needed to inform those decisions.

And then we also, under assessment, address repair and replacement activities. That used to be a separate committee, but we folded it under assessment, but as you can see there, you know, we address what repair and replacement techniques are available and what the associated requirements are that must be met.

And then, so the inspection committee deals with how you actually do the inspections. So, you know, assessment says we'll go look at this, but the inspection committee is responsible for figuring out well, how do you actually do it and, you know, what equipment to use, you know, what procedures and techniques should be used, and then, you know, what are the associated uncertainties associated with those.

So, you know, a big effort we have under the inspection committee is building of mockups and administering, having vendors come to the EPRI NDE Center and perform exams of these mockups, and then, you know, those mockups have embedded flaws in them and we can then identify what the uncertainties are, you know, what's the level of precision for each of the inspection techniques, you know, for the different components.

And then the last committee is the mitigation committee and it's really responsible for, you know, dealing with how SCC can be prevented or reduced, and it's really through, you know, chemical means is what we're referring to there.

CHAIR BALLINGER: This is Ron Ballinger.

I'll ask a leading question with respect to inspection. Jim and I recently participated in a committee overseas relating to some very small cracks that were found in PWR piping and they were not found because, at least initially because they weren't looking for them, number one, and the techniques to find them were based on looking for fatigue cracks, not stress corrosion cracks.

Is there something now going on at the NDE Center to develop additional qualification devices, if you will, to bridge that gap?

MR. PALM: I'm going to phone a friend on that one. So, Bob Grizzi is going to be presenting later. He's in the NDE Center, so, yeah.

And maybe I should clarify here, you know, so for piping exams, at least within the BWRVIP, I mean, the only -- we have BWRVIP-75 which augments Generic Letter 8801, but for a lot of the piping exams, we're relying on ASME procedures.

What I'm really referring to here is the requirements for reactor internals inspection where, you know, the BWRVIP is the only game in town, so to speak, so.

CHAIR BALLINGER: Thanks.

MR. PALM: Okay, so I'm just going to talk about these, you know, five technical topics that I thought might be of interest. So, the first is going to be our reactor vessel integrated surveillance program for second license renewal.

Just to provide a little bit of background, the U.S. BWR fleet has been using an NRC-approved integrated surveillance program since 2010 to monitor RPV embrittlement and satisfy the 10 CFR 50, Appendix H requirements.

So, you know, every plant in the U.S. has to have a surveillance program. You know, most of the PWRs have their own individual programs. In the BWR fleet, we have an integrated program, and that program, what it does is it combines surveillance materials from across the fleet and also includes data from an already completed BWR owner's group supplemental surveillance program.

And this integrated program came about to resolve fleetwide limitations in the original BWR surveillance programs, and what I mean by that is the surveillance programs for the BWRs were designed and the vessels were fabricated and put in place before the current requirements on surveillance programs were known to be.

So, in some cases, you know, these

original BWR surveillance programs didn't have baseline data, they didn't have complete characterization of chemistry, and also some of them included materials that were thought to be limiting for the RPV, but then as our knowledge of reactor vessel embrittlement changed, different materials were found to be limiting than what was included in the surveillance programs.

So, our integrated program aimed to provide a more appropriate representation of the limiting beltline materials for each plant, and then it also optimized the total number of capsules to be tested by the BWR fleet.

And the simple explanation of that is there's no point in testing the capsule for which you have no baseline data because you've got a data point that you can't compare anything to, so rather than waste the time.

So, the NRC approved the program initially for 40 years and then shortly thereafter, the BWRVIP developed an extension to address 60 years of operation, but this program has 13 plants serving as hosts, so those are the plants that we actually pull the surveillance capsules from and test them.

For the remaining 21 plants in the fleet at the time the program was defined, we deferred the testing of those capsules, but we do keep them as standbys for contingencies if, you know, if one host plant needs to shut down or other issues arise.

But the program basically has 15 representative plate heats and 15 representative weld heats, and those heats provide data for all of the member plants. So, you know, we have a matrix that identifies, you know, which plants uses which material as its representative material to address the limiting material in the reactor vessel.

So, you know, recognizing that plants or that the fleet was going to be potentially pursuing second license renewal in the 2015 time frame, we started the development of an extension to the ISP and that was approved by the NRC and it's BWRVIP-321A.

And fundamentally, the program looks very similar to the original 60-year program, so that is 15 representative weld heats and 15 representative plate heats are staying the same. You know, the linkage of, you know, who uses which representative material is staying the same.

What we really just were aiming to do is figure out how can we get higher fluence surveillance data? So, the biggest issue is the existing fleet was designed and built with three surveillance capsules in each vessel, and at the end of 60 years, we would have tested all of those surveillance capsules. So, how do we get an additional -- how do we get data that's high enough fluence to address the 80-year period of operation?

Well, we looked at the data we had available and we found that for seven of the representative materials, we already had high enough -- yeah, EPRI IT strikes. Yeah, yeah, so, okay, hopefully we can defer that until break time. Yeah, yeah, it's not quite the blue screen of death, but it's second to that, so that's why I paused.

So, for those, you know, 30 materials though, we did find that we needed higher fluence data for 23 of them, and so what we are doing is we are building a specialized surveillance capsule holder and it is going to position surveillance capsules several inches from the outside diameter of the core shroud to obtain the radiation conditions that are accelerated as compared to normal BWR capsule conditions, but still within the range of BWR RPV conditions.

So, what I'm saying here is we're taking our previously tested materials from the, you know, surveillance capsules, and we're machining that material, you know, the broken specimens into sizes that can be used for reconstitution, and we're putting them in these newly fabricated capsules.

And we can't put them at the existing capsule locations because they won't get fluence fast enough to provide us meaningful data in a timeline that works. We wouldn't get the data before the end of 80 years.

So, we're putting them in an accelerated location which is attached to the BWR core shroud. You know, typically, they're attached to the RPV wall, but we're also making sure that we're not baking them beyond flux ranges that are not representative of BWR flux ranges.

So, this is, you know, without specifying a dollar amount, this is going to be a very high-ticket item, but it's going to provide the surveillance data for the entire U.S. BWR fleet to support SLR.

CHAIR BALLINGER: As a practical matter, the BWR vessel fluence is ten times (audio interference) times below, that big of an issue?

MR. PALM: So, I think what you're saying is could we use PWR data?

CHAIR BALLINGER: Very few of the PWRs are ever going to exceed anything in 80 years, and if they aren't, certainly the BWRs are not for the same material.

MR. PALM: Well, these are unique materials to the BWR fleet.

CHAIR BALLINGER: Okay, so they're different.

MR. PALM: Yeah.

CHAIR BALLINGER: The reactor vessel materials are different, oh.

MR. PALM: Yeah, I mean, there are some instances where some of these weld heats were used between Ps and Bs, but for the most part -- all of the plate materials are going to be unique and there's only a few instances where the weld materials overlap between the PWR and BWR fleet.

MEMBER PETTI: And how many different reactors are these capsules going to go in?

MR. PALM: Just one.

MEMBER PETTI: Just one?

MR. PALM: Just one. So, all 23 materials are going to be loaded into one plant, as I said, attached to the core shroud. We're going to install it in 2023 and a 12-year radiation period, and we'll be withdrawing in 2035, and at that point, we'll then, you know, depending on which plants actually pursue SLR, we can then decide which materials we will actually reconstitute and test.

MR. SCHULTZ: Nathan, Steve Schultz. Is the specimen reconstitution a well-accepted practice now?

MR. PALM: Yeah, I would say yes. I mean, we have a number of plants that already have, you know, they voluntarily reconstitute. So, you know, I said most plants have a design built with three capsules.

Well, some plants do have a fourth capsule because they reconstituted early in life, you know, and there's a number of examples where, you know, we have tested those reconstituted capsules and they fit the trends very well. There's no indication that, you know, reconstituted samples are second to an original.

MR. SCHULTZ: Good, thank you.

MR. PALM: All right, so next, I'm just going to kind of talk about our aging management approach for SLR.

So, you know, I mentioned obviously, you know, plants are now looking to pursue an 80-year license, and several years ago, the BWRVIP recognized that and recognized that, you know, we needed to address the question of whether our guidance needs to be revised to address 80 years of operation.

And first and foremost, you know, we feel our guidance continues to be effective in proactively detecting and addressing age-related degradation, and, you know, our position is that most of the elements of an effective aging management program are not impacted by consideration of longer operating periods and need not be revisited to address operation beyond 60 years.

So, you know, things that are hopefully rather obvious are, you know, okay, the scope of the program, you know, which components you need to look at, the NDE methods, you know, administrative controls, corrective actions, you know, all of those things should be fine to just continue as-is.

Furthermore, you know, looking at our operating experience, we don't see any adverse trends. So, you know, and I'll talk a little bit -- well, at the end of my presentation, I'm going to show some examples of how we've collected operating experience and statistically looked at that operating experience.

And, you know, we don't see anything heading in an adverse direction. Rather, you know, contrary, in looking at a lot of the data, what we see is it indicating that a lot of the IGSCC cracking occurred relatively early in plant life and we're not seeing a lot of evidence of new cracking in recent years.

MR. SCHULTZ: Is that because of changes in water chemistry practices?

MR. PALM: Well, we think that that is a contributor to it. You know, we also think that perhaps, you know, some of the instances of IGSCC could have been driven by like localized fit-up stresses, residual stresses, and that once the cracks cracked, those stresses relieved and, you know, the driving force maybe, you know, isn't quite there anymore.

So, yeah, so those are two explanations, but, yeah, clearly, and like I said, I'll show you some plots and you'll see, you know, the benefits of the water chemistry.

And, you know, one of the locations that we think might be most susceptible to those kinds of fit-up stresses would be like the core spray piping and I'll show a slide of how the crack growth rates have evolved on that slide.

So, you know, we do feel that the fleet is actively monitoring and evaluating the fleet experience and, you know, we, as part of the aging management program and it being a living program and following the NEI 03-08 protocol, you know, we revise our guidance as appropriate to address our operating experience.

So, really where that leaves us is that the revisions to the aging management guidance that are needed to address operation beyond 60 years are really limited to those elements that include time-dependent factors.

So, the first step that we took in looking at our guidance and trying to address its applicability to SLR was to review the guidance and identify where we had time-dependent factors that could impact the guidance adequacy or applicability.

And what we mean by these time-dependent factors are that, you know, they're factors associated with age-related degradation that directly or indirectly correlate with total accumulated operating time, so notably neutron fluence and fatigue cycles.

So, you know, the longer you operate, the more neutron fluence components can be exposed to and the more fatigue cycles it may see, but, you know, with respect to fatigue, we also note just because you operate longer doesn't mean that it's going to be a linear relationship with the fatigue.

You know, if you look at cumulative usage factor calculation, we know that plants accumulated a lot of fatigue cycles early on, but, you know, have, as time has gone on and plants improved their capacity factor, you don't see as much fatigue cycles.

So, you know, if a piece of guidance doesn't contain these time-dependent factors, our position is that the guidance remains adequate to manage the effects of aging.

MEMBER HALNON: Nathan, real quick, on the time, I understand it's CUF and the neutron fluence, but the trend is going to be towards load following, which will different types of cycles on these materials. Is that considered in the CUF and the fluence? I mean, are you confident that those are fully encompassed?

MR. PALM: Well, yeah, load follow would certainly impact the cyclic loading. And so, you know, our guidance basically tells you that you have to monitor, you know, those fatigue usage and the procedures for monitoring the fatigue usage would just account for --

MEMBER HALNON: It will pick those up.

MR. PALM: -- load follow, yeah. You know, in terms of fluence, most of our, well, our calculations really include a linear extrapolation of fluence, so load follow would actually reduce fluence, so that would actually help our case from the fluence perspective.

MEMBER HALNON: Or it will if it's, if the fluence is constant from the standpoint of where it's located in the core. When you're load following, you could be pushing that --

MR. PALM: Yeah.

MEMBER HALNON: -- down further or you could be pulling it up.

MR. PALM: That's true, but the plants all have their own fluence calculations and the guidance, and this is kind of what I'm going to get at here at the bottom of this slide is that the plants have to confirm the applicability of our guidance.

MEMBER HALNON: Okay.

MR. PALM: And the way they do that is we establish fluence limits. They have to do their own fluence evaluation to determine, you know, what the exposure is for the individual components, and in order for them to apply our guidance, they have to demonstrate that they're below those fluence limits.

MEMBER HALNON: Okay, so there's a real-time connection between what's happening in the plant.

We're not just resting on curves saying hey, they're all going in the right direction.

MR. PALM: Right, and we don't -- we haven't made bounding assumptions for the fleet, like we haven't said well, the plant doesn't, the fleet doesn't need to check this fluence limit because we're going to make an assumption that everyone's going to remain bounded. No, we haven't done that. There's an onus on them to do their own calculation and make sure that they remain bounded by the guidance.

MEMBER HALNON: Thanks.

MR. PALM: So, I already touched on some of those points here. So, really our premise is that, you know, the aging management guidance should be linked to engineering-based parameters like fluence or cumulative usage that are predictors of onset or progression of age-related degradation.

And, you know, those parameters, they're not based on any specific operating period. So, like you said, if you load follow, you're going to accumulate fatigue faster than if you don't load follow.

So, essentially what we did is we looked at our guidance and we looked for those elements, and we've developed new guidelines that I'm going to talk about on the next slide that puts things in terms of these engineering-based parameters as opposed to a specific time frame, and we put the onus on the owners or the licensees to confirm, you know, that they remain bounded by these engineering-based parameters.

So, there's three reports we've, well, two are written and one is in progress. The BWRVIP-315 is a reactor internals aging management evaluation for extended operation, and this report documents the technical evaluation of the adequacy of the VIP guidance to continue managing age-related degradation of BWR reactor internals for operating periods exceeding 60 years.

And it also identifies revisions to our VIP guidance for reactor internals even to address extended operation, so really what this means is where we had a time-based limitation before, you know, we've now revised it to be more of like a fluence or fatigue-based limitation. You can see down there in the blue box, that report is currently under review by the NRC.

The next report is BWRVIP-329 and this is a probabilistic fracture mechanics analysis of BWR RPV welds to address extended operation, and this provides a technical basis for continued relief from ASME

Section 11 RPV weld examination requirements.

So, what I mean by that is there's a legacy report, BWRVIP-05, that provides a basis for BWRs not inspecting the circumferential welds. That report was developed because those welds are largely inaccessible for examination, and so this report essentially serves as an extension for that BWRVIP-05 report.

But, you know, following that approach I've described of using engineering-based parameters as opposed to a specific lifetime, the criteria for applying this report are specified in terms of end of life reference temperature values.

And then lastly, we're working on this report, BWRVIP-316, which is similar to BWRVIP-315, but it addresses the RPV as opposed to the reactor internals. Any questions about that topic before I proceed?

Okay, so the next topic I wanted to discuss was irradiated stainless steel fracture toughness guidance update and impact. So, you know, the BWRVIP has been collecting data on irradiated stainless steel fracture toughness since the mid to late 1990s and, you know, we collected that data and we evaluated it to determine correlations between fracture toughness and neutron fluence for conditions representative of BWR operating conditions.

So, you know, we had to collect this data and develop these correlations because they were essential in dispositioning flaws in irradiated core shroud welds. So, you know, I mentioned we started finding these flaws in the mid-1990s.

We used fracture mechanics to determine whether they were acceptable for continued operation or not, but, you know, we needed to have some way of knowing how tough the material was going to be at the end of plant life.

The NRC reviewed and approved those correlations and, but in doing so, they also indicated that they would like the BWRVIP to obtain more fracture toughness data actually for weld materials.

So, just keep in mind that most of the flaws we find are actually in the heat affected zone as opposed to actually in the welds, so a lot of our data was base metal and heat affected zone, and we wanted -- the NRC indicated that they'd like to see industry obtain more weld data.

So, we set about some testing programs to do so and we tested materials from the Zorita and Barseback materials, and when we evaluated those test results, and this was in the early 2021 time frame, we found that they showed lower than anticipated fracture toughness for weld metal and a potential non-conservatism in our fracture toughness correlations that had been published in BWRVIP--100, Revision 1-A.

So, that resulted in us issuing a Part 21 transfer of information notice to all of the BWRVIP members in February 2021. We also issued that to the PWR members. I should have put that on this slide because, and I think it will be talked about later, the PWRs said it would use some of this information also.

But so, we've had several meetings between the BWRVIP and the NRC to keep the NRC informed of our efforts and progress to address this potential non-conservatism.

So, the current status is that we have developed a revised fracture toughness versus fluence correlations for weld and base metal, and we're going to be submitting those to NRC for review and approval in mid-2023. We had a pre-submittal meeting on that topic just last month.

So, part of the good news is that the lower bound fracture toughness that's used for linear lasted fracture mechanics evaluation remains the same for weld and base metal. It's just that you reach this lower bound fracture toughness at a slightly lower fluence for the weld than what we had previously thought.

But the overall shape of the fracture toughness curve, you know, in terms of toughness versus fluence flattened a little bit, and what that means is, you know, historically we've used a limited load approach for evaluating flaws for lower fluences and we're finding that limit load alone cannot be treated as the governing flaw evaluation method for those low fluence components.

You're going to need to use elastic plastic fracture mechanics methods in conjunction with the limit load up to the point, up to the fluence value where, you know, you can switch to using LEFM and the lower bound fracture toughness, so --

CHAIR BALLINGER: So, this has no impact on the 80-year projection?

MR. PALM: Good question. Well, so these new guidance methods are -- and keep in mind, so the 80-year guidance is guidance. We didn't reach any conclusions. So, the plants that use -- the plants are going to need to use this new guidance as they operate out to 80 years.

Now, like I said, the lower bound limit isn't changing. So, a lot of components are already, you know, whether they operate 60 years or 80 years, they're going to be at a saturation point and they're going to be using that lower bound fracture toughness anyway.

CHAIR BALLINGER: Got it.

MR. PALM: So, we've developed a plan for addressing the impacted inspection and evaluation guidelines. So, you know, this document deals with the fracture toughness approach, but they're going to -- our flow evaluation guidelines reference these fracture toughness values.

So, right now, we have a number of reports that contain flaw evaluation guidance. We're going to develop one generic flaw evaluation guideline that's going to supersede the guidance in our individual component reports. We may need to issue interim guidance for core shroud inspection intervals, but we anticipate completing all of these actions by the end of 2023.

So, you know, this is just kind of one example of where we're, not necessarily operating experience, but we're revising our guidance to incorporate, you know, the latest information that we have, and this is an instance where we found that we had an adverse impact on our guidance and we're addressing that.

And as I mentioned, you know, we've had numerous interactions with the NRC, be it, you know, focused meetings on this topic, but also our annual and quarterly technical exchange meetings, and we're going to continue to keep the NRC abreast of, you know, what we're doing to address this issue.

All right, so the next topic is our mitigation and validation efforts in platinum deposition modeling. So, I'll say it right now. I'm a mechanical engineer, so this is -- talking about this stuff is a little bit foreign to me, but I'll do my best.

So, you know, the BWR fleet started operating with normal water chemistry, eventually developed hydrogen water chemistry. That transitioned to noble metal chemical addition, which, you know, this hydrogen, noble metal chemical addition is adding noble metals, platinum, during shutdown.

But then now, you know, currently, almost all of the plants in the U.S. use On-Line NobleChem which is, as it sounds, they're applying it at regular intervals during, you know, while the plant is operating.

But, you know, this is an IGSCC mitigation method and the method relies on the deposition of platinum nanoparticles on reactor internal surfaces, and these particles, they catalyze the recombination of hydrogen and oxidants, and then that lowers the electrochemical potential at the surfaces, which in turn reduces crack initiation and crack growth rates. That's the intent.

And what plants currently do is they monitor the ECP. They have probes that go into the coolant environment and actually, you know, measure the electrochemical potential to ensure that adequate platinum is available to mitigate cracking.

We also have efforts where they do scrapings and measure the platinum loading. So, you know, for a defined amount of area, you need to have a certain amount of platinum mass deposited to kind of meet the requirements for ensuring that, you know, you can claim that you have adequate mitigation.

But one of the things that we are looking into though is validating that the sufficient platinum catalyst is deposited on reactor internal surfaces and adequately distributed with the expected particle size, density and spacing to reduce oxidant surfaces to approximately zero.

So, a simple way of saying this is like, you know, does what we're seeing here, is it really, truly representative of all of the components in the reactor internals? So, does the global measurement apply to the local measurement everywhere?

So, you know, because obviously we can't look at every single surface in the reactor internals, so how do we know that the surfaces, you know, where we are looking are truly representative of everywhere and how do we know that this platinum is distributed over all of the reactor internals?

Now, you know, we do know that we have an overall reducing environment by virtue of our RCP probe measurements and also we have evaluation of inspection data that provides confidence in the mitigation effectiveness, but we want to -- we have this research underway to truly understand and have confidence in the technique.

So, we have work in progress being performed to identify criteria when a plant component surface is covered well enough with platinum particles to behave fully catalytic and therefore to reach IGSCC mitigation.

So, you can see here some examples of FE-

SEM work that's been done. You know, the bottom picture shows distribution of platinum surfaces that have been achieved in lab conditions, and then the top is an evaluation of an artifact retrieved from the plant.

And we have work to date that shows us relationships between the platinum mass loading and the interparticle distance and ECP versus platinum loading or mean interparticle distance, but we have, we're also doing studies on laboratory-prepared specimens and harvested plant artifacts to validate, you know, that what we're seeing in the field can relate to the laboratory results.

And then we also have computer modeling of the platinum deposition ongoing, so that's looking more at, you know, how is the platinum being circulated within the reactor internals, and which components is it being deposited on, and then again, we're using the retrieval of artifacts from within the reactor to try to benchmark what the modeling is showing us.

CHAIR BALLINGER: Sort of a practical question. Is this work really due to the fact that we've seen something that requires us to do this or is it a situation where we'd like to reduce the amount of platinum that we use, and so we're going to figure this out so that we can justify reducing the amount? Because it's not cheap.

MR. PALM: Yeah, well, I would say it's a you don't know what you don't know question, and, you know, so someone brought this up at one point where it's like well, how do you know that you have good distribution everywhere if you're only taking measurements at certain places? And so, we're trying to do work to address that question.

CHAIR BALLINGER: You can't disprove a negative.

MR. PALM: Yeah, well, right, right, but we can improve our confidence, I suppose. And one of the things we would like to do though is there are some components where, right now, we don't know enough to say whether it's mitigated or not.

And, you know, like an example of that is like the up or downcomer region. So, we're doing work looking at, you know, can we model and can we convince ourselves that we are getting sufficient deposition in that region to treat it as mitigated, and then maybe in the future, ultimately be able to take credit for lower crack growth rates?

You know, right now, we're just saying,

you know what? We don't have enough confidence, and therefore, we're treating that component as if it's non-mitigated.

You know, when we do flaw evaluations, we're using normal water chemistry crack growth rates, and our inspection intervals for those components are established based on an assumption of normal water, you know, chemistry crack growth rates, so that's part of it, yeah.

And, you know, this ultimately too may change. We may go away from that loading requirement to a different, you know, doing the scrapings and calculating the mass loading. We may come up with different parameters that we feel better quantify how active the mitigation is.

Okay, so this is my last topic. I got a little bit behind schedule here. I'm going to talk about inspection data collection and the inspection and evaluation guidance optimization.

So, historically, the BWRVIP has spent significant resources to collect information on degradation identified in BWR RPV and reactor internals.

So, you know, every BWRVIP member, after performing exams required by the VIP, has compiled and submitted that information kind of in a summary level to the BWRVIP, and then ultimately, we've taken that data, compiled it, and on a yearly basis, we submit the information to the NRC also.

But, you know, we kind of recognized that that really wasn't the best way to be doing things. We didn't have a real quantitative way of evaluating the data.

So, beginning in 2018, we started building an inspection records database, and that database includes detailed inspection data, including the inspection technique, coverage, relevant VIP demonstration for UT examinations. I mentioned that earlier about the inspection committee.

It includes the detailed flaw characterization data, so, you know, where the flaw is located, how long are they, how deep are they, and all of the U.S. BWRs and some international BWRs contribute the detailed inspection data.

So, what's happening is the members are feeding their inspection reports directly into this database now, so there's no detail that is being lost. It's not summary level. It's everything.

And what we've also done is in certain instances, for certain components, we've gone back and we have brought all of their historical data into this database, and the database also includes environmental data, and this includes, you know, water chemistry technologies in use and water chemistry excursion details.

So, you know, I mentioned earlier plants start with normal water chemistry, you know, transition to hydrogen water chemistry, then noble metal chemical addition, and the on-line noble chemical additions.

So, you know, we have that timeline built into the database that can be mapped against the flaw, the individual flaw information for a plant.

We also have the fluence data, and in some cases, this is summary data, and in some cases, it's very detailed data, but, you know, we can look at distributions of cracking in comparison to distributions of neutron fluence.

MEMBER HALNON: So, can you look at -- it's been a long time since I've looked at this, but I guess what I was curious is I remember starting up the BWRs and whatnot and having an online noble system not working for quite a while.

So, the point is can you look at this data and do you track that out-of-service time or lack of chemistry --

MR. PALM: Yeah, yeah.

MEMBER HALNON: -- integrity? Can you look at that and backtrack it and say oh, now we know why you're degrading?

MR. PALM: Yes, so, and we've done that to some extent, like we've tried to look at, you know, on an individual plant or flaw basis, we've tried to see if there are increases in crack growth rate at times that correlate --

MEMBER HALNON: Okay, so that data is collected?

MR. PALM: Yeah.

MEMBER HALNON: Okay, good.

MR. PALM: Yeah, so we have a separate, you know, EPRI maintains a separate chemistry database and we essentially just link the two.

MEMBER HALNON: Right, and there is some link to the INPO data that they catch in their plant data systems?

MR. PALM: Yeah, I think --

MEMBER HALNON: We're not going to go into the details of that, but I know that they also track.

MR. PALM: Yeah, I think what we would have here would be more detailed than anything INPO would have.

MEMBER HALNON: Yeah, theirs is high level, but that's how they get their plant index, not the score, but the plant index.

MR. PALM: So, just high level, this database includes a comprehensive suite of statistical tools for comparing and characterizing data sets.

So, yeah, I'm not sure what more I want to say about that, but, you know, we can look at t-statistics, other statistical tools to identify whether there's a relationship between certain trends and things of that nature.

And as this database matures, we're now considering how to apply the resulting data correlations and trends to refine our aging management guidance, and we've already done some to a limited extent.

But the potential applications include improved quantification of SCC mitigation by hydrogen water chemistry technology, so that includes the noble metal chemical and On-Line NobleChem.

We're looking at, you know, refining periodic inspection program requirements based on improved understanding of SCC susceptibility derived from field inspection data.

We're assessing, you know, margins associated with experimentally derived SCC crack growth rate correlations to arrive at a comparison of experimental crack growth rate correlations with apparent crack growth rate correlations derived from field data.

And then one other thing we're looking into is can we demonstrate that once crack arrest occurs, a return to active flaw growth is highly unlikely?

So, I saved the best for last, I guess, right? So, here is one, you know, kind of example. This is plotting core shroud apparent crack growth rates, so what I mean by that, what I mean by apparent crack growth rates is these are based on field measurements.

So, this is data, you know, that we have where we've taken an individual flaw and we have measured it more than once and calculated the crack growth rate just based on well, what was the change in dimension, you know, over a period of time?

And you see there that the blue line is the normal water chemistry crack growth rate and then we have different lines for the different hydrogen water chemistry regimes, but they all stack up on each other fairly well, but you can see the On-Line NobleChem, you know, is clearly giving us the lowest crack growth rates, and really hovering very closely to zero crack growth for 70 percent of the data or so.

So, you know, I made the comment that yes, we're doing the work to better our understanding of how platinum particle spacing impacts catalysts and mitigation, but you can see here this provides pretty good evidence that hydrogen water chemistry and On-Line NobleChem, as we're doing it today, does reduce core shroud crack growth rates.

CHAIR BALLINGER: So, you used the word apparent crack growth rate. I understand what that means, but to me, it asks the question once the -- have you tried to put uncertainties on some of these numbers?

MR. PALM: Well --

CHAIR BALLINGER: I mean, because you're up there flatlining --

MR. PALM: Yeah.

CHAIR BALLINGER: -- in effect.

MR. PALM: Yeah, our next slide -- well, I need to -- yeah, let me -- here you go. So, here is the uncertainty. Now, I mean, so where does the uncertainty come from? It's really a result of the inspection technique.

And so, we have these NDE demonstrations that I referred to earlier, and we characterized the uncertainty in doing those demonstrations, and then so this plot is showing the crack growth rate with the uncertainty included. So, you can see that when you look at this --

CHAIR BALLINGER: You can see, but I can't see it.

MR. PALM: Yeah, well --

(Laughter.)

MR. PALM: I hope you can see there it's with, you know, the orange plots, which is that's the mitigated. That's the hydrogen water chemistry. You can see that it's pretty much a vertical, about zero. I mean, in a lot of cases, we actually, you know, calculate negative crack growth rate. You know, that's clearly an artifact of NDE uncertainty.

And I guess, you know, very small at the bottom, I'll point to the fact that we have 4,083 data points, so that's 4,083 individual core shroud flaws, and, I mean, these can be as small as three-eighths of an inch or so. So, many of them are very tiny, but we treat them independently.

CHAIR BALLINGER: Oh, I see what amounts

-- you know, nobody's vision is that good here, but maybe in two orders of magnitude in uncertainty? I mean, I can't see the numbers.

MR. PALM: Well, it varies based on the data point, right? Yeah.

CHAIR BALLINGER: In other words, there's clearly no overlap at the top?

MR. PALM: Yeah.

CHAIR BALLINGER: Okay, okay, I'm just -- I'll have to look at it when I can expand it.

MR. PALM: Yeah, well, I think one of the key points that we wanted to make is the hydrogen water chemistry technologies are, you know, this data shows they're effective at reducing crack growth rates, and when you consider the uncertainty of the inspection techniques, there are really few data points that actually suggest that there's any crack growth occurring at all.

All right, well, this is my last plot. So, this is an example for core spray piping and I'd say it, you know, shows similar trends as what was on the previous slide, but again, you can see there that the vast majority of the data really is showing zero crack growth for hydrogen water chemistry conditions, and, you know, especially when you're considering the

UT uncertainty.

So, in the case of core spray piping, you know, most of the flaws appear that they've been dormant. They haven't grown for many years. The improving NDE capabilities have been effective in reducing the NDE, or reducing inspection uncertainty, and many of our high crack growth rates from initial studies were the result of NDE factors more so than actual crack growth.

So, Jim has pointed out to me that I'm way over time, so --

CHAIR BALLINGER: Well, it took us a while to get started too.

MR. PALM: Yeah, so just to summarize, you know, the VIP is a living program focusing on aging management and safe operation. We'll continue to monitor and evaluate material and component degradation across the BWR fleet both domestically and internationally, and information gathered is being used to guide inspections and flaw evaluation methods, and/or validate methods that mitigate IGSCC.

CHAIR BALLINGER: So, in all of the previous, most, if not all, of the previous slides, there's been a pointer to a report of some kind that's available. That's not the case here.

MR. PALM: Yes, that's a good point. I don't think we have anything published at this point.

CHAIR BALLINGER: Is there plans?

MR. PALM: Yes, certainly there's plans. I was trying to think of what might be the most near-term thing. So, you know, I didn't mention it, but one of the things that we used this database to look at was we had this phenomena of off-axis flaws in core shrouds.

So, these are flaws that are kind of going perpendicular to the weld, and so we used this database to compile data on that and we're going to be publishing a report in the near term on that effort, but I don't know --

I do not think it will be publicly available, but, yeah, so I'm sorry I'm working through this in my head, but I don't think we have anything publicly available yet that contains, you know, this level of information. I think certainly in the future, we will, but nothing to date.

CHAIR BALLINGER: Okay, now I'll refer to the oracle, Member Halnon. Is anybody asking a question?

MEMBER HALNON: I don't have any members asking questions --

CHAIR BALLINGER: Thanks.

MEMBER HALNON: -- or consultants.

CHAIR BALLINGER: Okay, so we very conveniently went over time, but now we're down to a unit of issue of 15 minutes, so we'll have a recess until 11:00 by our warp speed clock on the top.

(Whereupon, the above-entitled matter went off the record at 10:43 a.m. and resumed at 10:58 a.m.)

CHAIR BALLINGER: Okay, it's 11:00 o'clock, we've got to pick it up again. I'll make an announcement, because I'll probably forget. They did find a food court person to show up this afternoon for lunch, if people want to go downstairs. You have to go a little bit early, that's my advice. Also, after lunch we will meet in the room next door, and hopefully that will solve our ongoing IT problems, whatever they are, who knows. Okay, so is it Bob? Okay, yeah, you're on.

MR. MCGILL: Thank you, good morning. I appreciate the opportunity to present on the materials liability program. My name is Bob McGill, I'm the program manager, and I've been with EPRI for about four years now. Previously I was a light water reactor consultant for over 15 years. So, that's my background, I'll go ahead, and have Kyle introduce himself.

MR. AMBERGE: Good morning, my name is Kyle Amberge with the MRP, and I've been with EPRI for coming on 11 years now. I came out of the naval reactors program as a consultant worker at Knolls Atomic, and Bettis Lab for almost 15 years, and then in commercial industry in New Jersey for five years after that. So, been in nuclear power programs, Navy, and commercial, since '92.

I've been responsible for project manager of MRP 227, and PWR internals for the last 11 years, as well as handling, operating experience, and engaging with the U.S. utilities, and international utilities related to OE, and inspections.

MR. MCGILL: So, we're going to tag team this presentation. I'll get started, Kyle will go over a couple items, and then I'll finish up with one last item. So, I'll go ahead, and get to the presentation agenda. I'm going to give a program overview, very similar to what Nathan did for the BWRVIP. And then we selected these five projects for industry engagements to talk about, because we've had a lot of NRC interaction with a few of them.

There's been a lot of NRC interest in some of these activities, so we thought it was appropriate to discuss these items here. So, just to give you an MRP overview of the program, it's been around since the late 1990s, the nuclear sector at EPRI established the NRP program to address generic materials issues that were occurring in the PWR fleet at the time, primarily stress corrosion cracking, thermal fatigue.

That was the genesis of the program to conduct research to be able to support plants in developing guidance for them to manage their plants safely, manage their assets. So, we conduct our research that provides utilities, and regulators with information to make technically sound decisions that are cost effective in managing materials degradation as our fleet ages.

Primary focus of MRP, actually two of them is supporting long term operation. There's been a lot of interest, not just with our domestic utilities, and extending operation over 60 years, but also international interest, we do have a large international membership. The second point that we are focusing on is knowledge transfer. There's a lot of new people coming into the industry, there's a lot of turnover, retirements.

So, we're trying to make our information that we have available easier for our members to access just to be able to help with knowledge transfer, and retention. So, this is a list of our MRP members, similar to the BWRVIP, all BWR utility operators are members of the MRP. We do have quite a few members internationally, both in Europe, and Asia. And again, this is similar to the BWRVIP.

We use a lot of that operating experience to help guide our research, and our guidance that we develop for all of our member utilities. This is the team that we have, the MRP team that we have. It kind of gives you a little background of where these folks are coming. But the point here on this slide is we have former utility engineers on the team, former NSSS engineers.

We have a lot of engagement, and activity with the ASME code, and we have advanced engineering training, really a lot of the folks on staff are subject matter experts that are recognized in the industry. This is the organizational structure that we have, as to how our research projects that are providing the oversight, and the guidance. We have what we call technical advisory committees.

These are committees that are made up of, and run by our utility members. MRP just facilitates these discussions that take place here. And these were the technical discussions where that happens, and where project prioritization comes into play. So, this is an opportunity for all of our membership to engage, and let us know as to what research is a priority for their plants.

And also to close the IMT gaps that Gene had spoke about earlier this morning. So, we are divided up with our internals, and integrity technical advisory committee, so that's all the research related to RPV integrity, and RPV internals. The pressure boundary tag handles pretty much everything else, all of the class one primary loop piping, any of the issues that are involved with that.

And then we have our inspection tack, much of the guidance that is issued by MRP results in management of degradation issues through periodic examinations. So, we're always looking for the inspection tack to improve our technologies, and processes that we conduct these inspections to make them more effective.

MEMBER HALNON: So, what about in the inspection world, the decline in skilled practitioners? Are you guys dealing with that in this committee, or is there another place in EPRI that's dealing with that?

MR. MCGILL: Bob, did you want to comment on that?

MR. GRIZZI: You'll have to repeat the question, I can't hear back here.

MEMBER HALNON: The decline in skilled practitioners with the new generations coming in. Are you guys dealing with that in this tack, or is there another place in EPRI that's dealing with the --

MR. GRIZZI: Well, for the group, my name is Bob Grizzi, I'm with the NDE program, and I'll say that EPRI as a whole from NDE standpoint, we don't necessarily address the resource issue from the industry standpoint. But we do do a lot of research that enables, or helps the practitioners perform their jobs more effectively, bring people up to speed more quickly in terms of enhancing the work force.

But the work force issue really is a commercial, and industry issue. We have a lot of projects that do address ways to facilitate the training, and the advancement of those practitioners that do come into the industry as new practitioners, but not necessarily are we involved in the commercial side when it comes to facilitating resources from a numbers standpoint.

MEMBER HALNON: Okay, so you pretty much leave that up to the utilities to take care of. I do see where that could affect the quality, and integrity of the inspections, but I understand you mitigate that by making sure the training of the people that do come in is where it needs to be, and their skills are where they need to be. Okay, thanks.

MR. MCGILL: Continuing on with the slides. So, the technical advisory committees for MRP, there's oversight that's conducted by the research integration committee. So, that's a committee that reviews the research that's being done through the technical advisory committees, making sure there's no redundancy, they handle funding issues, and that type of thing.

So, it's a higher level, managerial type committee. And then again, similar to the VIP, this reports up through an executive committee, which provides then oversight for both the MRP, and the steam generator management program, provides oversight for the PWR materials issues, the aspects of the research that we're doing to support PWRs. Any questions on that?

So, we're going to go ahead, and get into the overview of major projects. Kyle will do most of the reporting on these. Again, these are topics which we think are very relevant, either work that's being done by the NRC on our behalf, or on the industry's behalf, and then talk about kind of what our engagement is with the industry, and regarding some operating experience, which is relatively new. So Kyle, I'll turn it over to you.

MR. AMBERGE: Okay, the first topic is related to MRP 227, and this is, as Nathan mentioned, the BWRVIP program has been around for 30 years, and this MRP 227 guidance is sort of a mirror image of the BWRVIP guidance, except it's applicable to PWRs. And this has been around now for going on 15 years, and initially was established for reactor internals of PWRs as they proceed into licensed renewal.

So, if a utility was interested in operating their PWR units beyond original license of 40 years, they would submit for a license renewal as you know, and use this document, would be one of the many documents in guidance space to perform inspections, and evaluations during LTO for PWR internals. NRC's safety evaluation has been requested.

These are generic guidance documents, and that helps streamline the utility's license renewal applications, both first license renewal, and subsequent license renewal. And for MRP 227 rev 2, that's directly applicable to subject license renewal, and right now we're in the process of working with our major vendors, and with the utility partners to address the NRC's request for additional information that was sent to us late last year.

So, we're in the process of wrapping that up, and should be submitting to them shortly.

CHAIR BALLINGER: So, this is the current revision?

MR. AMBERGE: Yes, sir. One of the things that we wanted to point out, as others have mentioned, OE is very important, and critical, doing aging management correctly. We have had some OE in the last several months related to core barrel cracking in PWRs, very similar to cracking in a BWR core shroud. So, we understand how important that is, and we have informed the NRC staff that this OE is something that might require us to update the guidance in MRP 227.

And we are already in conversations with the technical staff to accommodate those, and we would intend to wrap that into the approved version rev 2A through the RAI process, for example. Part of that is the NEI 308 process in, and of itself has the emergent issues protocol, and one of those, the tools in that area is a focus group. So, the industry has setup a focus group, and I'll talk about that in a second.

And that is meant to help guide, and inform the decisions that are being made relative to what needs to change in the guidance, if anything. And the point of this is MRP 227 guidance, just like any other guidance, is a living program. The industry group, and EPRI are going to continue to engage with the NRC technical staff to address any OE that comes up, and make relevant updates to the guidance on a timely basis.

So, we've done this before, this is part of what we do in the NEI 308 process. So, next slide. So, relative to this core barrel OE, industry group earlier this year restarted a focus group. We had a focus group based on OE back in 2018, and 2019, and relevant to some OE at another PWR in the U.S. So, we restarted this focus group consistent with the NEI 308 process.

We held our first meeting early last month with the utility advisors, and the industry consultants, and contractors. Identified a few actions to go off, and address, some related to analysis, and some related to testing, and other repair options for example. And these focus groups typically are a subset of the industry peers, and industry experts, and we target -- we only need them to be active for a short period of time.

Typically a year, sometimes more, so that's the intent. We'll get through this OE event, and update the guidance in a smart, and informed fashion. Relative to another major OE event is the stainless steel SCC in France. We also stood up a focus group last year, brand new focus group to look at this. EPRI continues to support this focus group in partnership with the PWR owners group.

We are preparing a safety assessment report, but it's currently out for utility member, and expert review at the moment. And applicability assessment report is in the process of being developed, and issued later this year. Again, the focus group will remain active as long as it needs to be, and the industry experts will be involved, as well as in conversations with NRC.

Next slide. The other part we've done, last year MRP published two related documents that are both public. A letter report related to current knowledge state of stainless steel SCC in PWRs, and this is specifically piping related SCC. And then we issued a technical report on stress corrosion crack growth rate, MRP 458. And this year we have a technical report that we're going to update, MRP 236.

Which is related to the state of knowledge in SCC of stainless steel. So, that's our updated OE report. Last time it was updated I think was 2016, so we'll update that again to a salient revision to reflect the French OE as the focus group brought up. So, next slide. The next topic is on stainless steel, irradiated stainless steel, and fracture toughness. This is a fallout from the BWRVIP program.

A couple years ago the BWRVIP program issued a part 21 report based on test results from fracture toughness testing of stainless steel welds in heat affected zones. So, we've been working closely with the BWRVIP program, and with our industry experts to address this for the PWRs. What's important to note is the implications for the BWRs is likely to be minimal, but there could be some significant implications for PWRs.

And that's because the PWRs have higher fluences than the BWRs, as somebody stated earlier. Next slide. So, our report, MRP 210, this is going back to early 2000s, very similar to BWRVIP data, our database is actually the exact same database in

BWRVIP, and we documented that there is a reduction in fracture toughness that occurs between one, and ten DPA, and that reaches a minimum, roughly around 10 DPA.

And so, we've been working with Westinghouse, those values of DPA by the way, the BWRVIP program, BWRs generally don't have fluences in excess of three DPA. So, the fact of the matter is they're not interested in much beyond one DPA, and certainly not ten DPA. So, we've been working with Westinghouse, and other technical experts to reevaluate the data set of fracture toughness.

And we are looking at do we need to make any adjustments? Could there be information that we could glean from our data set that would make it more applicable to PWRs? For example fluence ranges, lower bound values may be different than what the BWRVIP uses, and may be different for welds in heat affected zones. So, the intent behind this is to update our technical report this year upon completion of this effort.

And then in process of this, we would get together with all the expert panel members, industry experts, to look at fracture toughness versus fluence relevant to the PWRs, and make a recommendation of how the PWRs should be addressing this part 21 report. Next slide. Any questions on the first two topics that I covered today?

MR. MCGILL: Thank you Kyle. Just one more project that I kind of wanted to bring attention to. This is regarding environmentally assisted fatigue component testing that we're doing. So, environmentally assisted fatigue is a phenomenon that affects materials that operate in the reactor water environment that results sometimes in lower fatigue resistance.

So, all of the U.S. PWR fatigue analyses initially were based on SM curves that were created based on air tests, testing that was done in an air environment. So, as plants move into license renewal, this is something that the NRC has required, that needs to be accounted for in plants operating 40, 60 plus years. And that's done through fatigue evaluations with a linear multiplication factor, called an FEN factor to account for these effects.

The FEN factor has been based on compact tension specimens in laboratories, and the purpose of this test is, the question came up is that relative to components that are used in PWRs, in reactors? These compact tension specimens are very small, there is other dynamics that could be going on, and larger specimens that are more representative of piping in PWRs, so this is really the objective of this test.

Is to find out if we have these more realistic specimens that are testing, is there a basis that we can develop in order to lower this FEN factor for future accounting for environmentally assisted fatigue, so that's the impetus behind the project. So, just a couple slides here kind of showing what these test specimens are. They're actually very thick, four inch OD piping that's been machined down.

So that you have a step change in the thickness here to account for to see what knowledge we gain there by what the step tests have done. Naval nuclear laboratories have done some of the pipe step changes before, and came up with some interesting results. The ability of the test loop is to not only do step change transients, and temperature, but also to be able to ramp the transients, which is more realistic with what the actual transients are, the pipe is experiencing in operation.

So, it's a very dynamic, and has a wide range of capabilities of testing that we'd like to do with this test loop. Just going straight to the test process that we're in. The unique way that we've developed these specimens, and are planning on doing the inspection of these specimens allows us to identify when initiation occurs, and also to be able to track crack growth as these cracks grow through the transients that they're exposed to.

So, it's not like we stop testing once cracking initiates. We're also able to track the crack growth, and establish what those rates are through the testing, until the conclusion of the testing. So, that's something unique about the work that we're doing. Just pretty much explained we're at the commissioning phase right now. We have some sample specimens that we're going to be installing, and commissioning the test loop with.

And this is to improve our understanding of the transients that are being applied, and the frequency at which they need to be applied for us to be able to initiate cracking in a reasonable amount of time. So, these specimens we're going to be doing thermal testing on, taking a look at the through wall temperature gradients, how they respond to the transients that are being applied.

And we also have the string gauge measurements that we're taking too. The whole purpose of the test specimens is to make sure if we put our sample specimens in, we want to make sure that we're going to initiate cracking.

MEMBER HALNON: This begs the question of timing, phase three, phase four, what are the targets?

MR. MCGILL: Well we're hoping to get just about finished with the commissioning at the end of this year, and testing, conclusion of the project is probably going to stretch into 2025.

MEMBER HALNON: Okay, so a couple years.

MR. MCGILL: And this shows kind of what the schedule is for this year. We're hoping to get through most of the commissioning, commissioning being the string bench marking specimen, journal bench marking specimen to be able to initiate cracks in those, and the test loop can do what we're planning on using for the actual specimens. That's all the slides that we had. If there was any sort of questions, comments, or other discussion, I'll take those now.

CHAIR BALLINGER: Anybody?

MR. MCGILL: All right, well thank you for your time.

CHAIR BALLINGER: Okay, now we have kind of a decision point. I'm told by Chris that if people want to go, and get lunch down at the little mini food court, which is down below, the best thing to do is to get in line now. If people want to go out, that's a different story. So, because there has to be some escort going back, and forth.

So, what I'd like to do is since we decided because of the lunch issue, to take an hour, and a half for lunch, and the best time is to start early, then I would propose that we do that now, and then do the steam generator stuff first thing after lunch. By the way, next door, where we actually can hear each other. So, that's what I would propose that we do.

I think since everybody that's going to be involved is here in this room, we can get together with Chris, and decide what you want to do, and then we'll go from there for lunch. But in any case we'll see people back here in that room at 1:00 o'clock. Thank you very much.

(Whereupon, the above-entitled matter went off the record at 11:25 a.m. and resumed at 1:00 p.m.)

CHAIR BALLINGER: All right, it's 1:00 o'clock, and hopefully everybody's had a chance to get a good lunch, or any lunch, I guess. So, we'll pick up with the steam generator management program, and I think Helen is going to do this. Thank you.

MS. COTHRON: Yes, thank you.

CHAIR BALLINGER: I didn't tell you that these microphones are extremely directional, and if you don't have it stuck in your mouth, we can't hear you.

MS. COTHRON: Is that better?

CHAIR BALLINGER: Yeah.

MS. COTHRON: All right. So, I'm Helen Cothron, I'm the program manager for our steam generator management program at EPRI. I've been at EPRI about 16 years, before that I was at Tennessee Valley Authority, and I managed their steam generator program for Sequoia, and Watts Bar. I'm going to give you an overview, it's a slightly different -- you've seen how the programs are setup, and how they're managed.

And SGMP is very similar to BWRVIP, and MRP. So, we do have a global membership, we've actually been around since the 70s, started as an owner's group addressing the alloy 600 mil tubing issues that were going on, and then became one of EPRI's oldest issue programs. We do have 100 percent of the U.S. PWRs as members, and we have one national laboratory, and 15 international members.

So, even though it seems like there's not very many steam generator issues anymore, everybody still knows that we do have most of the, or a lot of the reactor pressure boundary, and it's a very important program still. So, this graph shows forced outage over time caused by steam generator tube leaks. So, in the 70s, we began doing research to try to understand the degradation mechanisms, and to develop inspection techniques.

We understood that a big part of that was sharing of OE, and by 1977, we had a rudimentary database where we could do that. By 1981, we had the first inspection guideline, and we began to develop guidance for chemistry control to mitigate the degradation that was ongoing. In the 1990s, we developed a guideline for monitoring, and taking actions when there was primary, secondary leak.

And in 1997, we developed the first guideline for assessing steam generator degradation. So, taking the NDE data, and predicting safe operating intervals between inspections. At that time, it might not even be a full cycle. People might have to shut down mid cycle, because of steam generator degradation. In 1997 the industry came together, and adopted an industry initiative for steam generators.

It was NEI 9706, very similar to NEI 0308, but specific to steam generators. It was adopted by all U.S. utilities, and then after that, we began to work with the NRC to update outdated steam generator technical specifications. And those specifications referenced six EPRI guidelines. The examination guidelines, the integrity assessment guidelines, two water chemistry guidelines, an institute pressure test guideline, and then the primary, secondary leakage guideline.

So, those are all referenced in the U.S. technical specifications, and several international specifications. This shows the materials in the United States steam generator fleet. You can see the majority of the steam generators are now using 690 thermally treated material for their tubing. This tubing has more than 30 years' experience with no reported cracking.

So, besides the material, which causes a problem for all material types, the only relevant degradation mechanism for this material is wear due to interaction with support structures. We do have 16 units that have steam generators with 600 thermally treated tubing. And although we have seen some cracking in this material, it's very minimal, and our inspection strategies, and our assessment methodologies can safely predict an operating interval for these units.

There's one utility that has one unit with 600 mil tubing, and they had planned to shut down that plant, so we're seeing where they stand. They actually had replacement steam generators on order before they are even on site, before they plan to shut the plant down. So, besides our six guideline documents that contain all of the requirements for inspection, and assessment, and chemistry control, we have the qualification program in SGMP for all the NDE techniques that we use, primarily 80 current.

So, we have a QA program where we qualify the techniques that are used to ensure consistent, and accurate inspections. We document that qualification, where we give instructions to the acquisition team, the analyst team, and we document also the NDE uncertainties that are associated with that particular technique. We also have an extensive database of eddy current data, and software for testing analysts, and automated analysis systems.

Those are generic qualifications, and all of the U.S. utilities require their analysts to have this generic qualification. But we also require when the people go to site, that they take a site specific training, and SGMP provides the software for that training. I talked about our degradation database that was established very early on, we update this at least every two years.

And now it's got a lot of data, and a lot of capabilities, it's a web based application. Utilities put their data in after each refueling outage, and you can see all the different tables that we have of data. Plants can use this data to make strategic planning decisions, like when to replace the steam generator based on data in the database, or when to perform a chemical cleaning.

And you can easily benchmark your plant to sister plants. There's a wealth of information in this database now. EPRI has made training a priority, and SGMP has 19 training modules that are in EPRIU now. This is a repository of training that is available to the utilities. We have training modules from basic components inside the steam generator all the way to the flow regimes that are in the steam generators.

So, everything you need to manage a steam generator, you can get in these training modules. Additional training that is going to be available soon is some very specific training for tube integrity analysis, where we go into details of the inputs that are necessary for these assessments, and how to develop those. And we're going to take our first try -- sorry, you've got a question?

CHAIR BALLINGER: Is the water box divider plate welds, and those kind of, is that part of this program as well?

MS. COTHRON: Yes, it is.

CHAIR BALLINGER: Okay, and there's been no issues related to those welds?

MS. COTHRON: There was some operating experience from France, where they had some issues in the welds of their divider plate between the channel head -- between the stub runner, and the divider plate, in that weld, and in the weld between the stub runner, and the tube sheet. So, we did a lot of work to decide if it was structurally significant, and determine that really the divider plate weld could be completely degraded, and not pose a safety concern.

It's mainly there to keep the hot, and the cold water separated. There's actually holes that flow will go through. We looked at all the accident conditions, and normal operating conditions. After that, we actually looked at what about if cracking is there, would it propagate over the life extension? And we determined that it would not. It wouldn't go through all the channel head, or through the tube sheet.

So, we do have guidance in the integrity assessment guidelines for visually inspecting that area. There have been people that have seen very tiny cladding issues, but nothing major at all.

MEMBER BIER: One other quick question, this is Vicki Bier. You had mentioned that there is plant specific training also. Is that just so that people understand the specific design, and material issues of that specific steam generator, or what kind of things would be covered in that?

MS. COTHRON: Yes, that's the -- so, they've gone through a qualification to be a qualified data analyst, or they sent their automated system through our training, now they go to site, and really take site specific data.

MEMBER BIER: Okay, thank you.

MS. COTHRON: We've always tried to provide tools for performing needed assessments in SGMP, and here's some software that is about to become available in the next year, or two. We're developing a software for determining the population of potentially high stress tubes in the alloy 600 TT fleet. This will more graphically show these tubes, and we really looked into the reason why they would be potentially higher stressed based on manufacturing practices.

We're going to develop a performance, and reliability database that's going to have data such as steam pressure, valley factor, margin to valves wide open, these are questions we're getting now from our utilities. We're going to put in data such as deposit composition, the density of the deposits, maybe the average height of deposits.

This will be used by utilities to again benchmark, and then trend their own deposit levels to see what the performance is doing in their steam generators. We have a prediction tool that we're developing for foreign object wear. The way we'll use this software is there's times when foreign material can be inside the steam generator, you'll find it during your visual inspection.

And because of the orientation, or the place that it is in the bundle, it's hard to remove it. So, this software will actually predict the wear, predict the risk of leaving those parts in the bundle. So, that will help utilities make better informed decisions on go ahead, and spend the dose to get this out, because it's a high potential for causing wear.

Or maybe it's far enough in the bundle in a low flow area, and we predict that it would be safe to leave it in the bundle.

We're going to develop some operational assessment software tools so that utilities will have software to validate assessments that are provided by their vendors. They could also do what if scenarios when they're in plugging situations. We have an eddy current simulation software that we are very close to being completed with. We're doing validation work now.

This software would be, for example you would want to put together a data set, so you'd test a new probe, or do some testing of analysts, and you don't have any physical samples. With this software, you can actually put in the details of a flaw that you would like to have simulated. So, a length, a depth, a voltage, a circumferential flaw versus an axial flaw.

And this software will simulate that flaw, and put it in a position where you can actually take that, and use injection tools, and put it in a data stream, and have a real simulated flaw that you can work with. And lastly, we're trying to develop a state of the art thermal hydraulic code. We've been working on this since about 2015.

The idea here is to take a commercially available CFD code, and put a user interface on the front so that someone that's not very familiar with CFD could actually put in the inputs, and it's star CCM plus. It would run in the background, do the major calculations, and then TRITON would then take those outputs, and process them in a way, again, it would be easier for someone that's not familiar with CFD to use.

We believe we're at the end of that process, we're hoping to publish that this year. Secondary side maintenance, and cleanliness has become the highest priority for our members. We're trying to perform research to answer questions like what is the trigger point for chemical cleaning, what should I look for? Is it an amount of deposit loading, is it where the deposits are, is there a specific value?

We're trying to do research to answer that question. The other question is how to measure broached hole blockage. That's when the deposits will pack into the support plates, and cause flow issues. There are some techniques to measure that. We're looking at all of the different techniques, and we're going to document the pros, and cons, and where the challenges could be.

Another question, we've recently revised our technical specification, and we have longer operating intervals between inspections. So, one question is should we still continue to do sludge lancing, and foreign object search, and retrieval every outage, or every other outage, even though we don't have eddy current available, or not required to do eddy current?

Then like I was saying before, thermal performance trending, how can we trend our thermal performance, what is that data telling us about how long can we go before we do some kind of cleaning? On the next few slides, I have our research that's ongoing in the different research focus areas. So, our highest priority again is chemistry, and fouling. And we collaborate with our chemistry department on a lot of these programs, so they're actually --

MR. BLEY: Can I ask a question?

MS. COTHRON: Sure.

MR. BLEY: This is Dennis Bley, I don't know if we got everything fixed, if everybody can hear me.

MS. COTHRON: Yes.

CHAIR BALLINGER: I think we're fixed.

MR. BLEY: On your last slide when you were talking about a tool to help people who aren't really experienced with hydraulics code to use it, makes me kind of nervous. I'm wondering what some of the other members think about that. It seems to me that opens the chance of not fully understanding the quirks in laying out the design, and using one of these codes where we can get some results that aren't convincing.

What have you done to make sure that doesn't happen with that tool? And again, I wonder if some of the members have some thoughts about that.

MS. COTHRON: Yeah, so when we would like for people to be able to use the code, they wouldn't be taking that code, and making decisions like steam generator design, or anything like that. The vendors right now are using ATHOS, and they have their own processors, and the ways they use things, TRITON, we hope is going to be a lot more advanced than ATHOS.

I suspect that when the vendors take TRITON, if they do decide to take TRITON, and use it, they would do so in the same way they use their ATHOS code. It would be people that are familiar with CFD, and thermal hydraulics.

MEMBER MARCH-LEUBA: So, this is Jose,

Dennis. I guess it would depend on the degree of validation, how thorough are you going to benchmark a resource? The problem with CFD codes is you have so many parameters to adjust, you can get any result you want. So, you have to have an automated call by guidance on --

MR. BLEY: That's where I'm coming from, but again, when you've just been -- the others spoke, maybe the things that are -- the dangerous parts are already setup before somebody applies this new interface.

MEMBER PETTI: That can certainly be done, I think. That was my thought, is that the --

MR. BLEY: I'm wondering if it has been done. It sounds like --

MEMBER PETTI: Yeah, and that there would be some sort of training to qualify them to use the tool, because you can get all sorts of answers on CFD, that's for sure.

MS. COTHRON: Yeah, and we are doing validation work, as we get cases, we do validation work, and we would have -- our idea is to have a user's group when we get the first working version. I suspect there'll be vendors on that user's group.

MEMBER MARCH-LEUBA: It could be a black

hole you get into, but if it's understood it's used for visualizing what are the features that are happening in the flow inside, instead of calculating the amount of vibration you're going to get, it's more of a visualization tool, I think.

MS. COTHRON: Yeah, and I don't think anybody would be using it that's unfamiliar to actually design, or do an operation analysis, or anything like that.

MR. SCHULTZ: Helen, Steve Schultz, before you go on, because this was, I think on your previous slide, or perhaps the one coming up. But you mentioned the revision to the guidelines associated with inspection, revision five, and that that allows longer periods between inspections. What is that typically now?

MS. COTHRON: So, the way we have longer inspection intervals is our technical specification that we just revised. So, it's -- for 690 thermally treated tubing, it's 96, you can operate 96 effective full power months between inspections. If an operational assessment validates that that would be a safe operating interval.

MR. SCHULTZ: Okay, so it depends on ongoing results. But that's a fairly long time, that's quite an improvement over what has been done.

MS. COTHRON: Yeah, and we really base that on operating experience. There's some 690 thermally treated units that have operated for years already, and very little wear. So, they're spending money doing that inspection, when they could do something probably way more important.

MR. SCHULTZ: And I noticed that the guidelines have many revisions, and I know that they're not recent originally, but is that generally the reason for the revisions, is that you're looking for program improvements, to look at those --

MS. COTHRON: Well, not necessarily, but we do include those. So, every time we have research results that would affect our guideline documents, we revise the document. If we have technology improvements, then we revise the document. So, that operating experience would cause us to revise. So, we don't publish additional documents. All of our requirements are in those six documents. So, every two years we look at those, and we ask ourselves has operating experience need to go in here?

Does new technology, does research results? And when we talked about the divider plate, that's a good example when we've got through with all of our research, and came to conclusions, and came to what we thought people should do, then that went into the next revision of the integrity assessment guideline.

MR. SCHULTZ: So, they're evaluated against those different criteria, or evaluations every two years?

MS. COTHRON: Every two years, yeah.

MR. SCHULTZ: Then if necessary for revision, then it's done?

MS. COTHRON: Yeah. Then if there's no revision necessary, we look every year after that to see. So, yeah, most of you can see the examination guidelines was the very first guideline, they're in the process of revision nine right now.

MR. SCHULTZ: So, you keep right up, it sounds like a very good practice.

MS. COTHRON: Yeah, we keep up.

CHAIR BALLINGER: So, there's a time interval between inspections, is there also a number of tubes inspected at that time that's determined plant by plant?

MS. COTHRON: No, it is in the technical specification if you're going to operate for 96 effective full power months, you have to do 100 percent inspection, that allows you to go that long between inspections.

MEMBER HALNON: So, once you get the equipment setup though, that's the key thing, the outages extend, it's setup once you're getting it going, you might as well do 100 percent. I mean it does take longer, but --

CHAIR BALLINGER: They're very fast.

MEMBER HALNON: Yeah. And then the dose is in the setup, and the tear down, so decon.

CHAIR BALLINGER: Now they're very fast.

MR. BLEY: Now they're very fast.

MS. COTHRON: Yeah, we've come a long way. Okay, so I don't know how I'm doing on time, probably need to wrap up. So, I'll hit the highlights for chemistry, and fouling. We're working with chemistry, we actually helped fund these projects for a hydrazine alternative. We have candidates, haven't come to a good candidate yet, but we know that it does have some help in environmental issues.

We've done a lot of work on dispersants, that's to keep the corrosive material in solutions, so that it can be flushed out through the blow down. And we're actually looking at does it have any effect on flow accelerated corrosion, or thermal performance, or can we say that it softens up the sludge pile that's there, and makes even sludge lance seem more effective?

Film products, the idea there is to coat the balance of plant components so that the corrosive materials don't come in upon startup, into the steam generators. I think I've talked a little bit about the rest of these things. Wear is very important for the 690 fleet. We want to make sure we understand the wear, and how to assess the wear in the tubes. A lot of times if you can understand the type of wear that's in the tubes, is it tapered, or is it flat.

It can really make a difference in your assessment, so we're continuing to look at that. And foreign objects is very important to us. So, we talked about predicting wear from foreign objects. We're updating our operating experience, and research results from foreign object wear. We'll continue to work on inspection techniques, and I think I've talked a lot about most of these.

One thing that we're doing is we're trying to develop a technique that can go on the outside of the tube, and size wear that's identified during a visual inspection, so like we said, I might have a 690 thermally treated steam generator. I don't have an outage plan for primary site inspection, but I would like to go in, and search for foreign objects, since I have a history of foreign objects.

But if I find something, then I've got to bring in eddy current equipment to size that wear that I see. So, we'd like to develop tooling that can actually size that wear from the outside. We have found a probe, and now our challenge is getting it miniaturized enough to where we can deliver it into the bundle. I guess the most interesting project in this nickel based alloys, is we're participating in a research project with EDF called SHERLOCK.

Where they actually took a retired steam generator, had 600 thermally treated tubing, they've taken it, and done the decontaminating, and they're all ready to start now, cutting parts out of that steam generator. One of the most important things that we think we'll get to see is their 690 plugs. They'll take some of those 690 plugs that have been in for many years, and do examination of them.

So, that will again, give us a lot of confidence in our 690 material. Then also they're going to take a chunk of a support plate that'll have -- they had a severe case of blockage of their support plates, so we'll have a support plate that comes out with the tubes, and the deposit loading in that lock, so we'll be able to study a lot of things with that, the deposits themselves.

We run eddy current prior to taking them out, we'll run eddy current again, how effective can eddy current tell you anything about the blockage inside the tube supports?

CHAIR BALLINGER: So, most of the newer generators are either broached, or egg crate, right?

MS. COTHRON: Yeah.

CHAIR BALLINGER: So, this steam generator in France, is that one of those?

MS. COTHRON: I think it has broached, yeah. So, there's a lot of research that would go in there. And the newest thing we're going to try to do, we're just stepping into this, is digital twins. So, a lot of people are talking about it, wouldn't it be awesome if you had a computer steam generator, and it's got all your data, all your performance data, and you can just sit down if you're a brand new engineer, or if it's been eight years since you've done an inspection.

And you can sit down, and say this is what my inspection data looked like last time, this is what's happened with chemistry, this is what my monitoring is telling me, and so this is the scope I should have. So, that's the dream. The first steps are to see what plant data we can get to give us some information. How can we safely store that data, and ensure that the plant feels comfortable with us storing that data.

How can we trend the performance, and just what all we can do. We actually have a vendor that has some experience in digital twinning with balance of plant components. Actually looking for megawatt loss, so they're going to be our partner as we step into this, and see what we can do. I'll talk a little bit about interaction with NRC staff. We meet with them, the corrosion, and steam generator branch twice a year.

This is a typical agenda, we just basically keep them up with what's going on. What OE do we know about, what research are we doing, what reports have we published. And when they need training, we offer that. And one example is in June of 2023, we'll hold an automated analysis workshop, and we're expecting about 20 people from the NRC, from the staff here, and the region to come, and learn more about automated data analysis. So, this is my summary -- sorry, go ahead.

MEMBER MARCH-LEUBA: Is that somehow integrated with application intelligence? We've heard people trying to use application intelligence to analyze result experiments. You have gigabytes of data.

MS. COTHRON: You're talking about auto analysis?

MEMBER MARCH-LEUBA: Yeah.

MS. COTHRON: Yeah, so I don't think our auto analysis system really has artificial intelligence. It does go by rules --

MEMBER MARCH-LEUBA: Soft learning?

MS. COTHRON: Yeah. It doesn't learn from itself, but as people do inspections, they can tweak the sorts, so that with people intervention we do make it better, and better, but it doesn't teach itself anything, yeah.

MEMBER MARCH-LEUBA: We hear people talking about using AI as a generic term to brief scan their results, and only flag to the operator things that look weird.

MS. COTHRON: Yeah, so that's what auto analysis does. You have a computer system that takes the eddy current data from the acquisition. It uses two separate algorithms to analyze the data, and it comes out with the results, and then it takes a lot less analysts to review.

MEMBER MARCH-LEUBA: At the speed that AI is growing, and the AI computer farms that are setting up over there in the desert, it won't be next year when you're doing this, it may be this year.

MS. COTHRON: Right. And you know we have array probes that go very fast, collect a lot of data, automated data systems are the way to go. And also we mentioned earlier that fewer resources in the analysis resources, this automated data analysis takes care of a lot of analysts.

CHAIR BALLINGER: On Jim's first slide this morning, I think it was Jim, it showed four pictures, one of them was a steam generator tube, I would call it rupture, but the president of the company definitely didn't call it a rupture. But that was not seen in an inspection. That was not seen in an inspection, so this auto analysis issue, what about false negatives?

That's the big problem, right? False negatives, and that's what this was, but I think it was a human false --

MS. COTHRON: Yeah, it was in the 90s. And with that tube, when that happened, we did a lot of work for understanding why they missed that indication, it had a lot to do with eddy current noise.

CHAIR BALLINGER: Yeah, well, and sludge, fouling, and stuff. But again, your auto analysis program would have to be able to find these false negatives.

MS. COTHRON: It needs to be able to find them, right. And one thing, because of that OE, we have a requirement that people actually measure the eddy current noise, and make sure that the eddy current noise in a place where you would be looking for flaws isn't so large that it would mask a flaw. And so, these automated systems, a lot of times they'll be doing noise monitoring.

All they're looking at is noise, and if anything above the background noise pops up, and they say this could be large noise, it might be a flaw. So, there's several things in these systems that'll flag something that some person has to look at. I'll stop here, unless there's any other questions?

CHAIR BALLINGER: Has there been a tube plugging related to 690 wear other than what would have happened at San Onofre?

MS. COTHRON: So, the question has there

been a tube plugging that would have --

CHAIR BALLINGER: With 690 wear.

MS. COTHRON: With 690 wear that would have led to what happened at San Onofre?

CHAIR BALLINGER: No, no. has there been any tube plugging on 690 thermally treated due to wear, other than the big problem that they had at San Onofre.

MS. COTHRON: Yeah, people have to plug wear, but not like what happened at San Onofre. The issue with San Onofre was tube to tube wear, and not -- we've never seen that before, and we don't believe that any other plant in operation will see that. But they do have wear associated with like the ABB, where the tube, and ABB will -- but, you know, if it gets to be 40 percent, by our tech specs, we have to plug it.

CHAIR BALLINGER: Has anybody ever actually had to plug one?

MS. COTHRON: Yes, yes.

CHAIR BALLINGER: Okay.

MS. COTHRON: Thank you.

CHAIR BALLINGER: Thank you.

MS. SMITH: Hello again.

CHAIR BALLINGER: Back again, now we can hear you really well.

MS. SMITH: So, this is Jean Smith again, for the folks on the phone. So, I'm going to share some information about our international materials research program today. So, international materials research, or IMR conducts programs to enhance the understanding of the damage mechanisms in materials used in both light, and heavy water reactors.

IMR collaborates with our other issue programs, or EPRI materials related programs like BWRVIP, and MRP. We also collaborate with the Materials Aging Institute in France, the U.S. Department of Energy, and the NRC. We participate in a number of international collaborative projects, and as such our projects, and results reflect a wide range of nuclear technologies, operating conditions, and service environments.

As I mentioned earlier today, IMR is also actively involved in internal, and external programs that support the identification, and qualification of materials for advanced reactors including non-light water reactors. Our IMR members are nuclear sector base funders, and come from both the U.S. utilities, and also a number of international members. Some of our international members are not also members of issue programs.

Some of our CANDU folks, or VVER utility members are only members of IMR, and not of a separate issue program. There's a little lag between here, and there. So, as Bob McGill mentioned before lunch, the MRP for example, consists of technical advisory committees. IMR on the other hand is really just one overall research integration committee that has four different technical strategy areas.

Reactor sustainability, looking at age dependent degradation mechanisms, fundamental research, which works to understand the microstructural effects on mechanical properties. Our technical strategy area on international reactors is looking to support long term operations of CANDU, and VVER designs, and our advanced reactors, and methods strategy area is looking at again, the qualification of materials for advanced reactors, and also the use of advanced methods for materials qualification.

And I'll share some examples of projects in all of those areas in this presentation. Our IMR leadership team consists of an executive sponsor, Henric Lidberg, from Vattenfall in Sweden. Our utility chairman is Otto Yong from OPG in Canada. We currently have a vacancy in our vice chair position. Our IMR staff are listed there as well, and our IMR utility members are folks from the different utilities that have expertise, and are interested in materials testing methods, or new reactors.

So, when Helen was presenting on her different projects, she had them organized by focus areas, and I wanted to take a moment to highlight the fact that our materials department issue programs, and materials programs all worked towards common materials researched focus areas, or MRFAs. Greg Frederick will share with you later the research focused areas that they use in WRTC, which are numbered a little bit differently, and have some different titles, or interests to them.

But MRP, BWRVIP, SGMP, IMR, we all organize our research under these same 12 research focus areas, or MRFAs. On this slide I list the projects that we currently have ongoing in IMR in 2023. You'll note that in MRFA two, which is stainless steel alloys, we have quite a few projects, and we have historically had most of our work in this area, and it's indicative of the fact that stainless steel alloys are prevalent in all of our designs.

PWRs, BWRs, CANDUs, and VVERs, and we currently have projects, at least one project represented in stainless steel alloys of each of those reactor types. For low alloy steels, and fatigue for example, we've typically relied on the issue params for research in those areas. The projects that we have ongoing now are related to a failure analysis of a low alloy steel candid component, and then also the support of our materials department project on the EAF component test that Bob shared with you earlier.

I will discuss a little bit about our water chemistry mitigation project on the qualification of potassium hydroxide for PH control in western style PWRs. Under MRFA nine, which is repair, and replacement, most of our projects here are in the area of additive manufacturing. And more specifically, looking at the degradation of components, or materials produced by advanced manufacturing methods.

I have an example of a project using machine learning in materials research focus area ten. And then under MRFA 12, that's where we do, we'll say the care, and maintenance of documents such as the MDM, and the issue management tables. So, to summarize, IMR conducts research in four technical strategy areas. We use the materials department aging issue cycle that I discussed this morning, and rely heavily on the MDM, and the issue management tables to help us prioritize, and categorize the work that we're doing.

As I mentioned, revision five of the MDM is in progress for completion this year. And in parallel, we have activities underway to develop MDMs for the advanced non-light water reactors, and then also light water SMRs. And these efforts are being led by IMR staff. We are also, as I mentioned previously, developing the issue management tables for CANDU reactors. So, looking at our first technical strategy area for IMR, which is fundamental research.

In this area we conduct research to understand the effect of microstructure on mechanical properties, and we also use technologically innovative approaches to support plant operations. Oftentimes, our IMR research projects are a derivative of research that was performed by one of the issue programs. For example, the work that was done by EPRI in its expert panel to develop the referenced stress corrosion crack growth rate curves for irradiated stainless steels that form the basis for code case N889 was supported by IMR.

And the project that we have ongoing is a derivative of that project. In the development of the disposition curves for the code case, many, many IASCC crack growth rate test segments were evaluated, and it was observed that some specimens tested in the same environment under similar conditions show statistical differences in crack growth rate. So, our project in IMR is looking at two pairs of specimens that are ostensibly similar materials tested under similar conditions that gave different crack growth rates.

We've used micro structural characterizations including microscopy, electron microscopy, EBSD, atom probe tomography, as well as tensile, and micro hardness testing to reconcile the difference in the crack growth rate behavior. This project is still underway, but we have observed in one of the pair of specimens, these are austenitic stainless steels.

That the ferrite content, and the orientation of the ferrite relative to the direction of crack growth were likely contributors to the difference in crack growth rate. Within IMR, we are funded, as I mentioned, through the nuclear sector base funding. EPRI also has technology innovation funding that is available for EPRI staff to provide proposals to, and funding is awarded now on a quarterly basis.

IMR staff also apply for numerous

different types of calls for funding, and we are currently working under two DOE rapid turnaround experiments. In support of continued plant operations, IMR has had the lead on the materials testing to support the overall nuclear sector program to qualify potassium hydroxide for PH control in western style PWRs.

So, we have performed crack initiation, and crack propagation testing on stainless steels, irradiated stainless steels, nickel based alloys in both potassium hydroxide, and lithium hydroxide water chemistries. In the course of our testing program, we have not focused on the absolute rates of crack initiation, or absolute rate of crack propagation. Rather the comparison between the lithium hydroxide standard water chemistry, and the introduction of potassium hydroxide in place of the lithium.

Overall, our materials testing program has shown no statistical difference in crack initiation rates, or crack growth rates in any of our testing programs. We do however have one testing program still underway, and it relates to non-irradiated stainless steels in hydrogenated crevice chemistry environments, and that work is still ongoing.

With respect to reactor sustainability, we look at things that are age dependent degradation mechanisms such as wear, fatigue, things that might have an effect on end of life properties for a reactor internals component. Materials harvesting is one of the most valuable means that we have of providing a realistic source of material for testing, particularly for long term operations.

EPRI, and IMR staff have participated in the international harvesting workshops co-hosted by NRC, and NEA in January of 2020, and again last fall in November of 2023 in order to connect with the global community to prioritize research objectives, and to coordinate these harvesting opportunities. One of the most -- I think one of the biggest take aways from these international harvesting workshops has been the participation by international regulators.

In January of 2020, we had regulators from 13 countries participate in that workshop. And it's been clear again, this past November, that regulators have a keen interest in results that come from harvested materials, and they recognize the value of these materials for extending the technical bases for aging management strategies.

It should be noted that decommissioned plants also provide an opportunity to perform NDE activities. Harvesting doesn't necessarily have to mean taking out a piece of material from a plant. But rather a plant that has been decommissioned is sort of in the ultimate long term outage. So, you have a little more leeway to be able to take the time to do some additional inspections that might benefit the continuing operation of the fleet.

An example of a project that we have ongoing is the examination of PWR pressurizer vessel materials, and welds. Materials have been obtained from Ringhals Unit Two in Sweden, and also Indian Point Unit Two to perform thermal aging studies. So, thermal aging at high operating temperatures can decrease toughness through changes correlated to phosphorous diffusion bring boundaries in some higher phosphorous, and nickel containing ferritic steels.

Advanced manufacturing is an important aspect of repair, and replacement within our existing fleet, and it's also an important characteristic of components that may be going into use in our future fleet. IMR collaborates internally with other EPRI programs such as MRP, WRTC, and also ANT, our advanced nuclear technologies group.

Externally, we are working with other research organizations, such as the Materials Aging

Institute, DOE, and NRC, and with utilities in the area of advanced manufacturing. An example of a project that we have where we are collaborating with the utility, Constellation installed a type 316L stainless steel additively manufactured thimble plugging device in Byron Unit One in March of 2020.

They intend to keep the device in place through September of 2024, at which time IMR will take the lead on performing some post irradiation examinations of the materials. And in the intervening years, Byron will -- well, in September of '21 they did take the thimble plugging device out, and did visual inspections. They deemed it suitable for continued use, and they will take a look at it again, if not already this month.

In parallel, there was a second, or a twin of this thimble plugging device manufactured that we are doing some examinations on. We will also do some comparative examinations of a conventionally made thimble plugging device. Since international is our first name, it makes sense that research to support our international members, and our international reactor designs, it takes place in our program.

It's been said a couple of times now that we have the lead on the development, and revision of

MDM, and IMTs. We also work closely with the folks in the iGALL, and help correlate EPRI products to iGALL products in working groups. One of the projects that we just reported on last fall had to do with irradiation effects on stabilized stainless steels for VVERs.

So, IASCC has been observed in reactor vessel internals in BWRs, and PWRs, and to a much lesser extent in the VVER fleet. The main difference is between the PWRs of western, and eastern designs has to do with the construction materials, so they primarily use stabilized stainless steels similar to type 321 material, and they have no nickel based alloys in their reactor internals.

Their operating environment uses a potassium hydroxide, and boron chemistry instead of lithium hydroxide, and they have higher operating temperatures. For this particular project, we investigated crack growth rates on some type 321 material that had been harvested from an operating VVER. It was irradiated to approximately 11 DPA, and we found that the crack growth rates of this material satisfied the PWR disposition reference curve given in code case N889.

So, as part of IMR, we deal with many

different regulators, and many different members that have different regulatory obligations. While our issue programs, MRP, with SGMP produce guidance that our U.S. members find necessary, or beneficial to meeting our domestic regulatory requirements, it's not necessarily the case with our international members. The value for those members come in the fundamental research, or the technical basis research that we provide to them.

So, where in an issue program at EPRI, MRP for example, might take data, or models developed in IMR, and apply it to, or incorporate it into the development, or revision of inspection, and evaluation guidelines like MRP 227, our international members take that same basis data, and develop their own aging management program to satisfy their local regulatory needs.

A lot of our projects actually have application to more than one reactor design based on the fact that it's mechanistic, or microscopic in nature. We have a project starting this year studying the cracking of Calandria relief ducts, or CRDs in CANDU reactors. It's basically a chloride stress corrosion cracking phenomenon, which could have application in many other situations in a nuclear power plant, and not just in a CANDU reactor.

Our current project however, is a lab to plant approach taking a look at -- sorry, Jim's computer went to boot. I'm just going to defer. So, we're going to start by studying the mechanism of the cracking, and basically try to understand the relationship of pitting as a precursor to cracking in this component. Use electrochemical testing to identify the domains of SCC susceptibility.

And then determine some future steps that the plants can actually take in order to monitor, and mitigate this cracking. And finally, with respect to our advanced reactors, and methods, we've mentioned several times again, that we are working within the materials department on a materials degradation matrix for the advanced non light water reactors. We've been collaborating with developers of these new reactor technologies, universities, and the Department of Energy.

Just last week EPRI, and DOE had an advanced reactor materials integration meeting where we discussed some of the materials of construction of advanced non-light water reactors, and the degradation mechanisms that are relevant in each of the reactor types for the different materials. Qualifying materials for use in these advanced reactors needs to be a collaborative effort. No one organization, or group of organizations will really be able to get some of these things across the finish line.

Whether it's in ASME code, or with respect to degradation mechanisms. So, working closely both as industry, universities, and national labs is going to be a very important part of that. Using advanced methods for materials characterization such as machine learning will allow us to more rapidly detect, and quantify some of these materials attributes. Machine learning, as we are using it at EPRI, has been based on convolutional neural networks, which uses supervised learning.

So, in our example that I have below, we're using machine learning to quantify defects in microstructures, in particular we're looking at void swelling of austenitic stainless steels. So, traditionally, characterization of a micro structure for void swelling includes the identification, and quantification of defects such as dislocation loops, cavities, and so on in the material.

It's a very time intensive process, and it requires a lot of training for the individual. There's often variation in the interpretation of the results as well. So, by using machine learning with this supervised learning approach where we teach the machine using actual micrographs, but also have a data set of synthetic micrographs that we introduce to the machine, we've actually done a pretty good job of quantifying void swelling in some micrographs.

So, for example the machine so far has done a very good job sizing the defects in the materials. With a little less success on quantifying, or estimating the density of the cavities that are in the microstructure. However, the overall prediction of void swelling in these austenitic stainless steels has been pretty accurate.

MR. BLEY: Can I? Yeah, it's Dennis Bley. On your last slide, you mentioned that you were also looking at new reactor trends, and when we get over there, we have much different chemistry going on, some possibly aggressive, that might not fit well within what we currently know. What are you doing in that area?

MS. COTHRON: With respect to the materials degradation matrix, again, we started with a format, and some of the degradation mechanisms that were pertinent to light water reactors, but we've certainly extended it to be specific to some of these advanced non-light water reactors as well, the molten salt, and the very high temperature gasses. We have not actively began testing in some of these areas, but we are working collaboratively to identify which of these first degradation mechanisms, or combinations of materials, and environment we should be taking a look at.

Our advanced reactors materials development road map gives us an idea of which materials classes, for example, the various types, or varieties of type 316 stainless steel that we need to look at. And also properties such as creep that are very important in these higher temperature regimes.

CHAIR BALLINGER: You okay Dennis?

MR. BLEY: Yeah, I guess so. I guess the worry at the back of my mind is we'll have new chemistry in small, restricted areas that we're pretty familiar with for light water, but maybe we'll be introducing things we just haven't seen before, and getting a handle on that as early as possible would be very helpful. But thanks for your answer.

MS. COTHRON: That's a good question Dennis, and that's a particular topic that came up last week when we met with DOE. Some of these crevice effects, or concentration effects in these new environments, that again, we haven't characterized materials performance in those environments.

CHAIR BALLINGER: I say this a bit tongue in cheek, but usually the best thing you can do for these advanced reactors is to get rid of the water.

MEMBER MARCH-LEUBA: Without flair, or ambience, we've been operating light water reactors for 60 years, and we still have active material research programs, and finding stuff. So, all these new reactors that go, and say look at how well we work in this particular respect, 60 years from now, they'll still be having advanced material problems.

CHAIR BALLINGER: I say it again, get rid of the water.

MS. COTHRON: There are some challenges to developing the MDMs for the advanced non-light water plants. If you recall, our first revision, or first issuance of the MDM was in 2004. So, we had the luxury of many years of operating experience in our light water reactor fleet when we developed the degradation matrix the first time. We're slightly putting the cart before the horse with the --

MEMBER MARCH-LEUBA: In short, I mean, the devil you know.

MS. COTHRON: Yes, exactly.

CHAIR BALLINGER: The first generation of our plants were lab rats.

MS. COTHRON: That's right, but they've turned out pretty well. So, somewhere along the line I was mentioning that we have been using machine learning to help quantify void swelling in austenitic stainless steels, and so far the machine is doing a pretty darn good job with its overall prediction of swelling. We are applying the same machine learning approach to a more rapid, and standardized assessment of platinum particle sized in distribution in BWRs, a project that Nathan discussed earlier today.

MEMBER PETTI: So, just a question, I mean calculating dots, there's tons of software that does this. How do you validate it? I mean the classic way would be to have someone do it by eye, but that's probably less precise than letting the computer do it. I mean you guys, I'm assuming you're doing some sort of cross correlation to convince yourself that the AI is doing --

MS. COTHRON: So, the modeling, or machine learning is based on electron TEM micrographs that have already been quantified, as well as the synthetic images, where the known quantities of defects --

MEMBER PETTI: Okay, so there's a standard issue.

MS. COTHRON: Right, there is a standard. So, I was really more in wrap up mode, so that was good timing.

MEMBER MARCH-LEUBA: You can mention this slide number, I think it's 16?

MS. COTHRON: Yes, sir, I'm on slide 16, thank you. And discussing our IMR interactions with NRC. We have a number of ongoing, and monthly meetings with both NRC, and DOE. One being our monthly materials research pathway meetings between DOE light water reactors sustainability program, NRC research, and EPRI. We have monthly calls discussing advanced non-light water reactor materials, chemistry, and component integrity, again with NRC, and DOE.

We have regular materials harvesting meetings with NRC research, where we discuss prioritization, upcoming opportunities for harvesting, ongoing efforts to obtain materials.

MEMBER HALNON: Jean, the place that you want to harvest the most, that people probably drop out of the participation because they're utilities no longer worried about their steam generators, and vessel integrity, and stuff, how do you get a hold of those people that have those materials that aren't participating anymore?

MS. COTHRON: Materials harvesting is so much easier said than done, as the folks at NRC have found out on their own recently with DOE, and trying to get some core barrel, or core shroud weld material from Songs. You're really at the mercy of the decommissioning company. So, Indian Point, for example, when their license turned over to Holtech from Entergy, it isn't really an Entergy support issue anymore.

So, for example Entergy, and I'm testing myself, so Entergy doesn't have operating Westinghouse PWRs now, right? ANO, and --

MEMBER HALNON: That's the NWNCE (phonetic).

MS. COTHRON: Right, so they don't have a vested interest in say inspections that we might do at Indian Point now that it's decommissioned. But the reality is Holtech owns the plant, and it's getting the agreement with the decommissioning organization, and getting them to prioritize, and allow us to get in is the more difficult part. What you're mentioning, to me falls a little more in the category of harvesting, or getting access to replace components from operating plants. So --

MEMBER HALNON: I was actually talking about the decommissioning plants, so --

MS. COTHRON: Yeah, I know. But for me, the utility company ownership, or letting you harvest is more relevant when they still own the plant.

MEMBER HALNON: Okay.

MS. COTHRON: I just had one more column over here, I just kind of got derailed, I forgot where I was, sorry. So we, EPRI, collaborate with NRC in the SMILE harvesting project. That's harvesting, and characterization of materials from decommissioned BWR, and PWR plants in Sweden. We are participating with both NRC, and DOE in a project under the NEA FDAIS program.

The FDAIS program is a consortium to provide access to irradiation facilities for the study of fuel, and structural materials. And we also have a long history of collaborating with NRC, and DOE in the area of nickel based alloy long term aging effects. And I'll stop there, my summary slide, or summary comments lose some pizzaz without the slide. So, anyway, but you guys have them in front of you too.

So, in terms of fundamental research, we support our international members. But by providing technical basis data to help them support their long term operations. We work to provide reactor sustainability, and to help all of our members with the existing fleet in long term operations, we support the development of the MDMs, and the IMTs, and provide research specific to our CANDU, and VVER operators.

And we are actively involved in the support of identification, and qualification of materials for advanced reactors, including non-light water reactors.

CHAIR BALLINGER: I have one question, the supports in harvesting, and things like that, I seem to remember that there's a plant that was slated to be shut down, that now the new owner wants to think about starting it back up again, and it's a very old plant, Palisades?

MS. COTHRON: Palisades, yeah.

CHAIR BALLINGER: If they were to start that plant up, would that have any effect on the issues that you folks would be dealing with? Because it's a very old plant, I'm sure they shut it down because of that. I'm just curious whether there's any thoughts on that.

MS. COTHRON: Well, there had originally been some plans to harvest some of the surveillance materials, and that was a DOE led effort on the surveillance capsules from Palisades. I don't know where that stands at the moment.

CHAIR BALLINGER: Probably complicated.

MS. COTHRON: Very complicated.

CHAIR BALLINGER: Okay, we're going to take a five minute break, we'll be back at I'm not sure, 2:20, how's that? That's not five minutes, but it's close.

(Whereupon, the above-entitled matter went off the record at 2:13 p.m. and resumed at 2:20 p.m.)

CHAIR BALLINGER: Okay, let's proceed, thank you.

MR. GRIZZI: Okay, great. My name is Robert Grizzi, I'm a program manager in the NDE program at EPRI. My background, I've been at EPRI actually since 2003. Before that I spent time with GE Nuclear in their inspection services department. So, I've got some background on implementation in the field, and then me, and my work with EPRI. So, I'm going to go over an overview of the NDE program for you guys today.

And I've selected some projects at random, sort of, with some rationale behind why they fit into this discussion, but it's just sort of scratching the surface. So, this is the content I plan to cover. A little bit about program structure, and our membership, our research focus areas, and then the projects that I picked out to share with you. Some discussion about fundamental, and strategic research, a little bit about the training program.

And then some things that I think are very important in terms of the NDE staff, and the EPRI staff engagement on the ASME code. So, real quick, this is where we report up to the Nuclear Power Council. You can see down there in the bottom left, the NDE is labeled as NDE RIC, and so research integration committee, we don't have a technical advisory committee structure.

Everybody within the NDE RIC is all the members that participate in one committee, or one meeting council. And this is the breakdown of our org chart. NDE, the NDE program falls under plant support, which houses a couple other entities as well, the NDE training, as well as the WRTC, the Welding & Repair Technology Center, which Greg Frederick will be presenting on a little later.

But on the left there, you can see the organization for NDE, and that constitutes the NDE reliability group, which is under Carl Latiolais, who is the senior program manager, and Ronnie Swain, who is over the technology portion of the NDE program, and he is also a senior program manager. This slide just gives you, must like the rest of the groups that presented here, a flavor of the membership within the NDE program.

We're a base funded program at EPRI, which means that everybody that's a nuclear member, is automatically a member of the NDE program. We also have the ability to be a supplemental member on some levels from an international standpoint, but this sort of gives you an idea about what constitutes, or what members participate in the NDE program. On the upper right there, you can also see we have some strategic alliances with other qualification, and research bodies around the world.

Korea, Sweden, Switzerland, Japan, we've had interactions with them on various levels, and we continue to work with them on various levels in a collaborative sense. So Jean spoke about a little bit, and I think some of the other presentations covered what we call our research focus areas. The materials programs share research focus areas, and they're set titles, and numbers, and one of them is inspection.

Well, obviously we can't share that one, because we have a lot of other areas that we focus on. So, we have our own set of research focus areas, and this sort of gives you a breadth of NDE program, the areas that we concentrate on. Within these ten research focus areas that you see defined here, typically there's around 50 to 70 projects that roll up to these focus areas in their appropriate focus areas.

The program itself over the course of the life of the program has got about 600 active products out there that are implemented, or in use, or technical bases that are supporting the membership. And the green stars on the right are just indicating some of the focus areas that I chose, some of the projects to highlight, and be a little more detailed about today in the presentation.

You can see, for those that know a little bit about the NDE program, one of the major components of it is the PDI demonstration area, where we provide the administration, and facilities, and the means for performance demonstration qualifications to support ASME code examinations of the reactors to meet their ASME code, and regulatory requirements. So, the first project here I want to talk about is where we're embarking on, or actually pretty mature on artificial intelligence, and machine learning with NDE data.

What you see there on the top left is digitized ultrasonic data. When I say digitized, it's collected through automated means. The data itself, ultrasonic data in its true form is an analog signal, but the automated aspect of it encodes it, so it gives you a digitized pixel representation that prescribes position based on the encoding when the automated data is collected for that particular component.

So, we're working on AI that goes in there, and basically flags flawed areas that it finds within the automated data, which then assists the analysts in being able to go, and look at the areas where they have to concentrate, or focus on further dispositioning things that have been flagged by AI. And this is still, the UT data for DM welds is an area where we're just getting into the development of it.

We have some more mature results based on the image on the right there, that you see, and that is actually another form of digitized ultrasonic data for a reactor vessel upper head penetration weld. So, the data was taken in an automated fashion, digitized, prescribed their encoded positions, and the sinusoidal image there is actually the weld that would be shown in the UT data when collecting data on a penetration that might be more outboard from the center of the vessel.

So, the weld would actually have a sinusoidal pattern versus just a circular pattern. What it shows there in the red are the areas within the ultrasonic data that the AI flagged as areas of interest. And in the next slide, I'm going to show you a little more about the real weight behind this. So, I'll hold off on, I don't want to ruin the surprise. So, in the bottom there, we're also looking at it for visual testing, both post processing, and real time AI, and machine learning for visual data.

And I don't know how many people here have been through the process of reviewing visual data that's been collected at a site, but there are hours, and hours, of visual data collected when they do enhanced visual inspections, or VT1, depending on what they're looking at. So, what we've been doing is developing the algorithms, and the Aim, and the graphic user interface that allows you to take the video after it's been collected, and post process it.

And part of the process in terms of people looking at visual data at a site is they look at it in real time while they're taking the data, while they're looking, and doing their inspections in the reactor internals, and then somebody reviews that data set, that video after the fact. And the post processing of the video is really where we see a lot of the leverage for AI.

Because instead of an inspector looking at 24, or 36 hours' worth of data, the AI flags the regions that it finds the cracks, or areas of interest, it logs it, it draws the box around it, like you see there in the bottom right. It creates the log in the register, and allows the examiner to go back, and look at those particular areas without being absolutely bludgeoned by just hours, and hours, and hours of video.

So, this is something that we feel is really positive, and something that should be leveraged, and we're doing pilot applications with this type of AI. We've done one, and we're getting ready to do some more within this --

MEMBER MARCH-LEUBA: A concern with AI for this application in my mind is similar to digital controls. Digital control, that's much, much better than an operator anytime, especially in the afternoon after a heavy meal, same with these guys. The problem is that white unicorn hiding in the forest.

When they mess up, they mess up royally. So, AI can only recognize what it has seen before --

MR. GRIZZI: Sure, it's only as good as what you train it with, that's true, that's absolutely true. And that's part of the development of the algorithms in the AI.

MEMBER MARCH-LEUBA: When you do this you have to think about the white unicorn hiding in the forest, and when you're talking about cracks that can -- that have to be logged in, you should always have very high probability of success --- but even then it's still difficult.

MR. GRIZZI: So, in the data that we're able to feed the algorithms now, we've got a range of flaws of crack opening dimensions, and locations such as this one that you see here, it's a really tight crack in the weld tow area. But from anywhere from 15 microns up to maybe 55 microns in crack opening dimension, so they are very, very small flaws, very tight flaws, that currently the algorithm has been trained with.

MEMBER MARCH-LEUBA: As with the issue I have with probabilistic risk assessment, the issue of completeness. You remember to check completeness from your training set, you have to try to achieve it.

MR. GRIZZI: Yeah, absolutely.

MEMBER MARCH-LEUBA: And keep thinking about it.

MR. GRIZZI: We refer to this as an analyst assisted AI, we don't rely on it 100 percent to make the call.

MEMBER MARCH-LEUBA: But you know how it is going to be used in the field, right? Only the segments that the AI flag are going to be reviewed.

MR. GRIZZI: Sure, but when they do the inspections in real time, they are actually, that's the first part of the process where they're finding the actual flaws.

MEMBER MARCH-LEUBA: That way you take the full forces into account.

MR. GRIZZI: Yeah.

MEMBER BIER: Yeah, I would like to expand on Jose's comment a little bit. When you say the analyst should be assisted by the AI, I mean that really is the ideal, because the AI is going to find certain things that a human may overlook, and vice versa. And the big issue in the human factors community, they talk about social loafing, right? There's four other people on the committee, they'll find it, so I don't need to look too closely.

And I think the same thing is a risk here as well, that you think the AI is going to find it, and there may eventually get to be best practices where the analyst has to first put in their own recommendation of what places they want to look, and then get a list of AI recommendations to kind of avoid that over reliance.

MR. GRIZZI: Yeah, to set the backdrop here a little bit too, and I probably should have said it, when I say AI assisted for the analyst, all of this data gets -- every single bit of this data gets reviewed by a real person analyst first, before the AI is put into place. So, the AI tends to be the secondary review, and that's where they're looking at leveraging AI at this point.

There is some work with the visual testing, where they're looking at real time, the ability to detect at real time through AI. But that's the major concern, what you guys have brought up, is that we don't want somebody that's doing the initial inspection to be relying on something else to tell them what's there. We want them to be able to make the call.

So, maybe even real time isn't real time, maybe real time is five minutes lag. Because one of the biggest benefits of being able to do it real time, or some short delay when you're dealing with an outage scope at a site, you're on the refuel bridge, and you're taking video, and looking for indications on these welds. Well, if you miss it, and the secondary review finds it, and that's being performed a day, or two later, you're no longer in the position to go back, and take a relook at that weld, that component.

So, there's an aspect to real time, or very close to real time AI that brings a lot to the table when it comes to doing these visual inspections. Again, the primary inspector is the one doing the initial calls, and reviewing the data. But as everybody knows, the best way to remove human error, is to remove the human a lot of times, right? But everybody is subject to human error when they're doing these types of inspections.

CHAIR BALLINGER: These inspections, now we're getting a little bit into the weeds I suppose, ensure that you don't miss something that removes all your margin. In other words if an analyst, or the computer program misses something that's there, that something is not going to reduce your margin to zero. Like all of a sudden you're going to get a tube rupture, or you're going to get a through wall between refueling outages.

MR. GRIZZI: Right. I mean that's hard to say, right now the way these processes are setup, is that there's a primary data analyst, and a secondary data analyst. Now, do they both miss it? Or does one make it, one person find it, and the other one doesn't? So, it's hard to say, because it's the same scenario though, do two people miss the same flaw when they do their secondary review, or does the machine learning, and the AI miss it? I don't know.

CHAIR BALLINGER: Well, I guess what I'm getting at is can you fix it so the probability of detection is 100 percent for flaws that would cause you trouble between inspection periods?

MR. GRIZZI: Yes, and that's a little bit above my head when it comes to how they map out the AI, and teach the algorithms, but certainly things that I'm pretty sure that they have -- pretty sure that those are things that some of the people that are dealing with these for looking at qualification aspects of both the UT, and the visual testing is what they're bringing into consideration when they put this into place as a practice, as one of the options for review.

MEMBER MARCH-LEUBA: Just warning, these

failsafe engineers fall in love with the engineering. We all do. And the older guys have to be looking over the shoulder of a 22 year old --

MR. GRIZZI: Thinking they've got the flaw of the problem, the problem solved, right, yeah. Okay, so --

CHAIR BALLINGER: I can tell you that these old eyes can't tell you whether there's a crack there.

MR. GRIZZI: This is our case study for the upper head inspection that I mentioned earlier when we were talking about the data. But real quick, the home run here is really on the upper right side. So, when you perform upper head penetration examination, you collect miles, and miles of ultrasonic data that has to be reviewed by the primary analyst, and a secondary analyst, and sometimes by the utility oversight.

So, we are at site, and we went through the whole process with the AI computer, and algorithms, and came up with equivalent performance of what the primary, and secondary, and analysts did for the data that they reviewed. And you can see here what AI did, is it flagged the regions that needed to be flagged, which clearly with the areas that were flagged by the actual analysts.

But what it did was it took that area, or that distance of data or data set from 4.4 miles of linear data down to 463 feet. So, you can imagine the onus it removes from maybe a secondary, or third reviewer. To be able to go in, and focus on really where they need to focus, and not necessarily get caught in the noise, right? So, this is really sort of the first pilot application that we ran it through last spring at Byron.

And we have another pilot application coming up this sprint at another utility site.

CHAIR BALLINGER: Before break, because you've asked about that.

MR. GRIZZI: Another area we're focusing on is what we call virtual flaws, creating virtual flaws in ultrasonic data. This is something that the NRC is really interested in as well, so.

There's, you may hear the term virtual flaw, and you may hear the term synthetic flaw. And the difference is defined there. But a virtual flaw is a flaw that really exits that we've collected ultrasonic data on, and then we're able to use that as we seek to be able to manipulate it within other, other ultrasonic data.

A synthetic flaw is a flaw that never really existed that they wound up creating through computer modeling, and software, and mathematical models, and whatnot. So, the second one there, synthetics flaws, has a little bit of work.

But we've gotten to a really good place with virtual flaw creation. We're sharing that information with the NRC. They are continuing both the research and the validation of the work that EPRI's done for virtual flaw creation.

What you are looking at here -- and I don't know your familiarity with ultrasonic data -- but as I mentioned earlier, this is digitized encoded automated ultrasonic data.

If you were to imagine a pipe that is to be -- a round pipe that was scanned, this would basically be the information of that round pipe flattened out, as if you were looking down the end of the pipe. So, basically, you're looking through the thickness of the material for a 360 degree rollout.

The information that you see, or the line of color changes there would be indicative of noise coming from the ID response of the pipe itself. You can see in the red box there is an actual flaw.

As I mentioned, with ultrasonic data

that's been encoded and digitized, it actually has three different dimensions. This is only one of the dimensions that you see on the screen. But when analysts look at it, they'd be looking at three different panes of information for the X position, Y position, and depth position relative to where the flaw is. So, but for simplistic's sake, I've just used this for easily to show pattern recognition.

And, you know, you look at this and you can see the before and after. And you say, well, big deal, that's just a copy/paste; right? Because that's easy to do.

But and you'll have to take my word for it, it's really actually a pretty complicated mathematical, and computational, and software issue to be able to get data manipulated without giving away the answer.

And that's what we've done. And the next slide really has some of the real benefit of why we're doing it and how we're doing it.

So, in the upper-right there is a end view of a pipe. And you can sort of see that there are some implanted flaws there. The red -- the red marks there, implanted flaws.

A physical sample there is shown in that picture. So, at EPRI we had probably, I don't know, six or seven hundred of these samples. So, in order to get a test set of data for procedure qualification you have to have 30 flaws.

Well, you can't put 30 flaws in that specimen right there. You can only put about 3 to be effective. So, now you start doing the math and you understand that you've got to have 10 or these or 12 of these to make an effective test set.

If you could create virtual flaw, you could potentially take a heavily-embedded specimen, like shown there on the bottom-left where all those red marks indicate flaws that are implanted, you scan it and you get signatures of flaws. You combine that with another sample that has no flaws to generate your baseline ultrasonic data. And now you have a whole bunch of different flaws that you put in and create a whole bunch of different test sets in a virtual, virtual state, and not have to make, you know, 700 physical samples to be able to achieve your, your program.

And in conjunction with that, it also allows you to build a lot of practice test sets. So, you can take those and give those to people for training purposes, for just-in-time training, for training before you come to do a qualification. Those are all really powerful aspects of being able to create multiple samples in a virtual, in a virtual flaw setting.

Does anybody have questions on that? Or does it make sense at least? I know --

CHAIR BALLINGER: I presume there's some way to validate?

MR. GRIZZI: Yes.

CHAIR BALLINGER: You've got, you put a virtual flaw in and then you go and find out whether the real flaw would actually look like the virtual flaw?

MR. GRIZZI: Right. Absolutely, yes. Yes.

And the other kind of fit is that you can take field-removed flaws, or field data that have real flaws in it, and use those real target flaws and insert them into your, your virtual mock-up. Right?

So, you get actual, real data from the field and you can use that as well. So there's some, a couple, you know, there's a lot of different aspects to it that bring a lot of benefit to the table for these things.

MEMBER MARCH-LEUBA: And I assume that heating one of those circle openings creates the 100 percent solidly, and run them through the virtual flaws and see what they think about it. Does it look right?

MR. GRIZZI: Yeah. So, that's a good point. We're not there yet, but that will be something that we do, yes.

MEMBER MARCH-LEUBA: Somebody that hasn't spent years in the field seeing the real stuff --

MR. GRIZZI: Right.

MEMBER MARCH-LEUBA: -- can see how it looks.

MR. GRIZZI: Yeah. And the NDE program, just I didn't really go into the depths of the resources in the NDE program, but we do have an extensive amount of very well-experienced field inspectors, managers, utility experience, vendor experience that all go into this research that we do, so.

MEMBER MARCH-LEUBA: The program has been following -- I have been following all these AI developments from the roots. And the bulk of money is expended in Pakistan with actual operators running it to even say, yeah, you missed that; no, you didn't. And it's the post-training that costs money. The real training costs $500.

MR. GRIZZI: Yeah.

MEMBER MARCH-LEUBA: Of CPU time.

MEMBER HALNON: Do you see this ever getting to the point where it could replace the field experience time requirements for raising to like an end-use point?

MR. GRIZZI: It can supplement it. And that's the other thing that we're working on is, you know, providing different means to accomplish, you know, your, for lack of a better term, your hands-on experience. Right?

Like, you might not need to be -- and it's very hard to collect the hours you need to collect in the field to become a qualified individual. But if you have access to this type of, this type of information on a supplemented basis, you can't do it, you know, if you need $500 of training you can't do all $500 from a lab situation.

MEMBER HALNON: Right, right.

MR. GRIZZI: But maybe, you know, --

MEMBER HALNON: Get some time credit for a degree requirements.

MR. GRIZZI: Right. Yep.

MEMBER HALNON: You know, sort of like that.

MR. GRIZZI: Yeah. And that is one of the projects that the NDE program is working on, days in code as --

MEMBER HALNON: Because that can certainly help the issue we talked about earlier with, you know, qualifying --

MR. GRIZZI: Yep.

MEMBER HALNON: -- you know, the new generation of folks.

MR. GRIZZI: Yeah. And that was we've probably got a half a dozen projects that I can cite that do just what you said. You know, they, they focus on how do we, how do we get people up to speed quicker. Right? How do we train them.

The code case that they're working on was a study in reduction of hours to reach a certain level of examination qualification. So, a lot of that kind of work is going on.

And we, so that's why, like I say, we focus on where we can impact it through the research, right, and through the things that we can do from a, from a NDE program to make the resources that are available to the industry better, you know, more proficient, more experienced.

But when it comes to actually developing that particular resource as a person to do the exam, that's not, not necessarily EPRI's swim lane when it comes to generating or trying to generate or bring that number up. You know, that's a, like I said, a commercial issue.

Okay. And another area we're heavily concentrating in is virtual reality technology. We have environments that simulate the PWR internals, the BWR internals. And those are owned by the respected programs.

And then the NDE program has its own virtual reality environment for a Westinghouse boiler containment. The entire containment we have in VR space. And they're planning on using that for modules for the EPRI training that's offered, the NDE training that's offered.

And, you know, the impetus behind this is, you know, the fact that the newer generation coming up learns differently, right, and they've got to be more engaged. So, you know, this is an opportunity to use some of the newer technology and bringing it into the fold in the nuclear space. And it does afford you the ability to go into places that you can never go into, or places that you'd never have access to, or barely have access to because you can only access it during the outage.

And now we've got these environments available for, for use with the training that we provide in the VIP, and the MRP, and within the NDE. So, these are used heavily in labs within the training, but they are also fully available to the members so that they can have them at their sites and use them as they see fit for communication purposes with management, for familiarization of components and space constraints, and just you name it, you know, they can use this type of environment to really get familiar with things that they wouldn't necessarily be able to touch and feel in the real world or with any type of frequency.

Yeah, I think I hit all the points there.

Another thing we're looking at is optimization of NDE examinations. And that's another element of reducing, you know, trying to facilitate resource issues. Right? We need to focus on the inspections that make sense, the inspections that become of a higher value and a higher impact to, to the industry.

The ones we focused on here, the impetus behind it was really the industry forming the focus group that was led by EPRI. But the industry is the one that came about and said, hey, we've got these examinations we've been doing for 30 or 40 years, and we haven't seen anything.

We need to look at really what the technical basis is behind why we're doing these inspections.

Is the material performance an issue?

You know, should we reset on when we do these inspections? And that was really the thrust behind optimization for these different components.

And we focused on the steam generator, the pressurizer, some BWR heat exchangers, reactor pressure vessel studs, and then some visual inspections that are associated with the PWRs for the, it was the be in one exam in code space. And it's just a general area look for general degradation and degradation or anomalies of the sort.

But, you know, the whole push behind this is that it really allows the plants to focus on where they need to focus from the safety standpoint. So, it's helping the plants focus resources and time where it should be focused.

The other aspect of it is the health, and human health aspect of it. Right? Any unnecessary work that's performed is work where somebody has the jeopardy of being hurt, injured, collects dose, and so on and so forth.

So, these are, you know, two of the major elements behind the optimization efforts.

CHAIR BALLINGER: I have another sort of philosophical question.

Any time you have a degradation mechanism that's time-dependent you could be having no problem for 3 years and you say to yourself, well, heck, we inspected this thing every year for 30 years and not found a darn thing. How do you assess whether or not if you wait another 10 years and don't inspect it you will, you would find something if you did?

So, as soon as you have these time-dependent aging mechanisms it becomes an important question.

MR. GRIZZI: Yeah. Any analysis work that's done, you know, using the probabilistic fraction mechanics, as well as deterministic fraction mechanics, they postulate flaw sizes and crack growth rates, you know, that are in ASME code. They apply sensitivity, they conduct sensitivity studies by changing a lot of different factors associated with it.

And then they also take into account flaw initiation. And part of this is over my head in terms of how the analysis part of it takes into account flaw initiation. But those are all elements that are considered in the probabilistic fraction mechanics.

CHAIR BALLINGER: So it comes back to margin.

MR. GRIZZI: Yeah.

The next slide just shows, so, with these technical bases that EPRI put together at the direction of the industry, you know, these were the pilot plants that had submitted the evaluations for relief.

On the left there you can see the different EPRI reports and the associated titles.

And then on the right are the pilot plants that were executing the implementation for the first time of these different reports.

If you were so inclined to really dig into it, these reports are all publicly available at no charge. So, you can go look at all the analysis that was performed for the different components here.

And I'm always open for questions. At least I can get you in the right direction. I might not be able to answer them personally, but just information for you to dig into if you feel so inclined.

The next thing I want to talk --

MEMBER HALNON: Question.

MR. GRIZZI: Oh yeah.

MEMBER HALNON: Were those accepted by NRC or are they still in process?

MR. GRIZZI: These are, all SERs have been issued, yeah.

MR. RUDLAND: Can I just make a comment?

MR. GRIZZI: Sure.

CHAIR BALLINGER: Now that we have microphones that work.

MR. RUDLAND: My name is Dave Rudland. This is really odd.

My name is Dave Rudland and I'm an advisor with the staff.

Ron, you asked about unknown degradation. And one of the things the staff is talking with the industry about is how to incorporate performance monitoring into these submittals of -- especially for extended periods where they're trying to optimize these inspections.

CHAIR BALLINGER: Yeah, I keep coming back to the issues that are currently under consideration.

MR. RUDLAND: And that's exactly right.

CHAIR BALLINGER: I mean, it's not that they wouldn't have seen them. They didn't see them because they weren't looking for them because they were assuming that it was a fatigue problem. Doesn't mean that those cracks wouldn't have been found if they were looking for them. And when they eventually did look for them, they found some of them.

MR. GRIZZI: Sure.

CHAIR BALLINGER: So, the issue --

MR. GRIZZI: Yeah.

CHAIR BALLINGER: -- now is to siding and things like that.

MR. GRIZZI: But in these --

CHAIR BALLINGER: There's a public meeting in April.

MR. GRIZZI: Yeah. April 27th there will be a public meeting on this, more on this and performance monitoring.

But I'll say that IGSCC, SCC has been a reoccurring issue through the course of history.

With these components there have been none. You know what I mean? So, like, you're looking at nozzle and radiuses, and nozzle to show welds, right, that they've been performing exams on forever, and have never found anything.

SCC is a well-known degradation mechanism that's manifested in many different places, and continue to manifest in different places.

And the example in France is a perfect example of performance monitoring. You know, that, that sort of gives you an idea that it doesn't need to happen here in the U.S. It could happen overseas; right? And we'd wind up getting the information from those examinations as well.

So, when you look at performance monitoring, you know, I personally think you have to take into account, you know, everything. So that that's sort of a plug for where we need to sort of go with performance monitoring when we talk about optimizing examinations.

MR. RUDLAND: Yeah. This is Dave Rudland.

The real tricky point is how much is enough, right, to be able to feel confident that if something unknown happens it would be discovered in a timely fashion. So, that's something the staff will be talking about.

MR. GRIZZI: I've got to go through this really quick here Jim says.

So, we also focused on balance of plant and LTO. We've got some engagement with NDE development to support a code case that's going to implement carbon fiber reinforced polymer repairs on service pipe, and safety pipe, and balance of plant. So, EPRI's done work in NDE to be able to support the implementation of the carbon, carbon fiber reinforced polymers.

We are also looking at work with guided wave of tank inspections for safety systems and tanks that -- tanks onsite that hold, you know, core flood, volumes of water that need to be inspected. They're just water tanks, but there's no real good way to inspect them right now. So, they're looking at using, you know, different means.

And we're looking at guided wave. It's something that we're collaborating with PNNL on. And it's something that, hopefully, if it shows promise it will be something that's pushed back into the commercial side of the business.

Another area in LTO and balance of plant is radiation damage on concrete bioshields. So, there's about 10 years' worth of studies that have been done on the analytical side at EPRI. And now we're also looking at continuing some of that analytical work, but also looking at how do you employ NDEs to be able to validate some of the degradation from a bioshield, from irradiation on the bioshields.

So, this is just more work. And there's work going on with some universities in Japan and EPRI's collaborating with, with hopes to publish the results this year.

Some fundamental research and some strategic research. We're doing research with irradiated surveillance capsules, the integrated surveillance programs.

One of the things we want to do is look at, you know, is there a way that NDE can be used to look at the reactor vessel itself and not have to continue to reconstitute and use these surveillance capsules that we were talking about earlier today.

You know, if you can develop the right level of NDE, no matter what the technique is, and you can actually go look at the actual material itself as opposed to having to do the destructive analysis on these capsules, well, that's a big win.

So, that's an area that we're looking at from a fundamental NDE development side of things.

And then on the bottom there we've got some early research. We work closely with ANT and WRTC on additive manufacturing and advanced manufacturing, and applying NDE techniques to validate, you know, the different components that they've made under those programs and need help to either validate or show them where they need improvements.

Real quick, EPRI training.

So, this is classroom training that EPRI offers to its members. And you can see there the list on the left and then the calendar on the right. But that just gives you a flavor of some of the actual classroom type of curriculum and training that the NDE program offers.

And then this is sort of the scope of it. We have the three Cs: classroom training, computer-based training, and then we also offer certifications for visual inspectors and ultrasonic inspectors. So, that's sort of the width, the breadth of the training program within the NDE program.

CHAIR BALLINGER: Who are these trainings open to?

MR. GRIZZI: These training --

CHAIR BALLINGER: Who can go to those?

MR. GRIZZI: These trainings are open to EPRI members. I believe we do offer some for people that aren't members. But those are under certain, like, you know, understandings or certain different contract terms, I guess.

CHAIR BALLINGER: What I'm thinking about is this is the NRC; right? You've got people that are reviewing --

MR. GRIZZI: Sure.

CHAIR BALLINGER: -- submittals and everything. Some of them have to do with NDE. Somehow these people have to either be hired, or trained, or get some kind of knowledge of what they're looking at.

MR. GRIZZI: Right.

CHAIR BALLINGER: And this is one way or one, this is one of probably many places where they could get it.

MR. GRIZZI: I don't know whether our memorandum of understanding covers between the NRC and EPRI. That's sort of above my pay grade, too.

But I don't know, there, I'm sure there are ways that stuff like that can be investigated.

MR. RUDLAND: This is Dave Rudland again.

Good question, Ron. And it's something that we were just talking about yesterday with EPRI and how we can get more involved in the computer-based training, as well as their onsite training they have.

CHAIR BALLINGER: Without an apparent

conflict of interest there; right?

MR. RUDLAND: Yeah, without. That's right.

CHAIR BALLINGER: That's right.

MR. RUDLAND: But that's something that we've done in the past. And it kind of went by the wayside, I think, with COVID and all that. And we need to go back at it, especially for our newer employees.

CHAIR BALLINGER: I mean, I say that because I think the EPRI NDE center is the repository for just about every kind of flaw that you could think of. And you're not going to find it anywhere else.

MR. GRIZZI: This is true.

This is my last, this slide and the next slide are the last two slides. And really it's there for your, your viewing at your leisure since you have the slide deck.

But this is everybody that you see on this slide is an EPRI staff member. Those that are highlighted in the bright blue are EPRI NDE staff members.

So, just be aware, you know, EPRI is heavily involved in integrating an ASME code. This is Section 11. There's also Section 3 involvement as well.

But as you can see, there are quite a few names on this list. And a lot of them are in this room that aren't necessarily NDE people but, as I mentioned, the ones in blue are where NDE is integrated in the ASME code.

And then this next slide is just the remainder of the Section 11 case groups. But, again, should be familiar names for a lot of people. And again, heavy, heavy participation in ASME code.

CHAIR BALLINGER: Thank you.

Apparently we're behind schedule, but we're not. Because I don't think that we're going to have to have a closed session. So, I think we're going to be fine, so.

I'm sorry. Forget I ever said anything.

Greg can introduce himself and then we'll get it.

MR. FREDERICK: I'm Greg Frederick. I'm the manager of the Welding and Repair Technology Center. I've been with EPRI 30-plus years. Been a program manager 12-plus years if you count the last 3 years. And a lot of us are, you know, putting those aside.

But so it's really good that Bob started out because my first couple slides I was really worried about time. He covered the organizational chart for WRTC to bring plant support together.

He covered a lot of the ASME support that we're engaged in. I think, I think your chart showed where WRTC and all the groups came together. So, I'll just jump over a couple of slides that I have, if they come up.

CHAIR BALLINGER: You're the only that can see.

MR. FREDERICK: I'll go ahead and get started. I, again, don't want to delay this too much.

But one thing I wanted to mention, that we talked a lot about the INT gaps and all the technology gaps that all the other groups and us have worked on over the years. WRTC also looks at those. We do focus a little bit more on balance of plant as well, right down to the service water components.

So, you know, there is a little bit of difference in what we work on.

So, you know, we, we go out and look for technology gaps in the industry, work very closely with our members to find those gaps. And then we, again, that's how we direct or look at what we work on throughout the year. So, we look very closely at our prioritization of projects and based on those gaps.

Still having trouble.

But, so that's, you know, the first part of it.

Second part is one thing that a lot I think don't know, at EPRI we have a full metallurgical lab, machine shop, weld shop, material testing facility that is, you know, state-of-the-art. So, if you ever come down to Charlotte, please take a tour of the labs.

We're very proud of our facility.

You can go ahead to the next slide. That's just what's in content of -- Don't need to cover this. Bob covered this very well.

Again, Bob covered this pretty well.

I just wanted to highlight this. One thing I didn't put in the organizational chart for WRTC is that we have started, again we were talking about workforce, building the workforce, experience in the industry. We're losing them very rapidly.

One thing that we have that started to implement in WRTC is we have a small we call them a bullpen of past utility members that we're starting to hire as contractors to deal with emerging issues.

So, we have a few, few of these retired utility personnel that are part of our staff now that can help us work directly with utilities on emerging issues.

So, that's kind of the way we're dealing with the workforce issues at EPRI, or within WRTC.

You can go on to the next slide, please.

Again, members are very current. Our current members are very similar to everybody else's. Other than, you know, because we're under the base membership. But we also have a few service vendors and other research organizations that are part of WRTC as well: IHI in Japan, Dusan in Korea, Westinghouse, Fluor, Framatone, are all part of our group.

The big reason that we have -- not the reason we have them, but a benefit of having these type of service vendors and researchers in our group is not only that we're working on repair, replacement, fabrication, mitigation techniques, we need to have the field deployable methods when we're done. We're not doing research to do research. We do a little bit of fundamental research, but it has to have a final implementation side.

So, these numbers help us make sure that we stay on focus and it's still deployable, and usable in the field when we're done.

Next slide.

So, again, as I started going through this already. Identifying the gaps, addressing the gaps, making sure they're field deployable.

But the two things that we have, you know, again, most of the members or most of the programs have already mentioned this, we work very closely with the National Labs, universities. We have global collaborations. And then we have our facility in Charlotte that we work, try to bring a lot of work in-house to manage.

And then, finally, the last two, two parts. Once you get it done, you have to implement that. So, we work very closely with, you know, ASME code, international code, to make sure that whatever we're working on is the technical basis needed to actually promote code through the process, and to help implement it when it's done.

So, we, we also do a lot of direct assistance. I think Bob probably mentioned this as well. We work very closely with the members when they're trying to implement some of this technology. We help them go through their regulatory requirements in different countries. So, it's a learning experience for us as well to find out what the differences are from country to country on what the requirements for approving different code cases.

MEMBER MARCH-LEUBA: Wait, wait. Don't take pictures. We need to watch this.

MR. FREDERICK: Me, too. Everybody smile. Good catch.

So, the big thing is finally to transfer the technology with our members.

We work very closely with our members. We actually have most of our utility members and other members, supplemental members directly engaged with all the projects that we work on in WRTC. We have coordinators, we call them, and they work very closely to help us make sure that the products are implementable.

You know, we do have a number of different methods of serving industry, looking for best practices, lessons learned from one utility to the next, trying to find out consistency and how people are doing things.

Again, workforce issues are a big problem. Not really a problem but because we have solutions. But, you know, our members are looking for very quick answers to questions that their predecessors may have known. So, we have forum sharing SurveyMonkey type stuff that we can go out to industry and find this information quickly. And then collect that information as best practices and lessons learned.

Next slide, please.

Again, wanted to show, I think it's been mentioned in everybody's presentation, we are very integrated in WRTC with all the other programs. Everybody, all the programs are integrated like this. But, you know, so we're not -- we do our own projects, for one. We have a list of prioritization of different technology gaps we're trying to address.

But we also supplementally help other groups as, you know, like a workforce to help other groups do work as well.

So, the areas that we're currently resource sharing with our generation group, the fossil site, we share equipment, personnel, people in the labs. So, very, very tightly knit group of people that you've heard from today and from me.

Next slide.

Just like everybody else, we have research focus areas. Ours do not match exactly what the Materials Group has. And some of ours do match, but Bob just presented.

We have -- I'll just go through this fairly quickly.

Material weldability and welding alloy development. This is the 690 stuff that you heard about today quite a bit, how it's welded, its weldability issues. We've had issues in the field. So, we come up with solutions to help overcome those issues.

We've developed new alloys to help make those issues go away. This is hard base alloys, nickel alloys. And the new alloys that are being used in some of the advanced reactors now, too. We have to look at those right now to determine how they are going to be fabricated, and can you hot bend them, can you form them, can you weld them and, you know, that sort of thing. Needs to be looked at now.

These materials do have different properties than the current materials that we use in the industry.

CHAIR BALLINGER: Are you doing anything with 625?

MR. FREDERICK: Six twenty-five? Six twenty-five is a fairly weldable alloy. So, not a lot. We have alloys that kind of replaced that over time, 182, and 82, and the 690-52 alloys have kind of replaced 625 more recently.

So, then the next one is RFA2, radium

material welding, material repair solutions. This is pretty -- I have a slide on this one later so I won't go into any detail here.

But we had technical exchange with the NRC, what, 3 weeks, 2 weeks ago? Two or three weeks ago. Focused on the radium material weldability and repair solutions, code, code and standards which is RFA6.

I think that was just the two main topics that we covered during that meeting.

So, I didn't, I purposely did not put a lot of those slides in this presentation, so that you can go back and look at those, if you need to. So, no duplication there.

Our RFA3 is looking at new technology. We're looking at all the industries out there, not just nuclear industries. Can we bring technology into the nuclear field that is successful in other industries? The petrochem, the industry pharmaceutical, anything, welding issues, repair issues, everybody's addressed them differently, so we're looking to bring new technology into our field.

RFA4 is the repair solutions for structures. That's tanks, canisters, that sort of thing. And I have a slide later talking about spent fuel canisters. So, that RFA covers non-pressure containing components.

And then RFA5 is, that's your small bore piping issues. That's your high cycle/low amplitude, or low cycle/high amplitude type vibration issues that small bore piping typically has. So, we have a whole RFA research on that.

I have no slides on that today. So, if you have any questions there, feel free to reach out to me later.

Codes and standards, everything we work on, RFA1 through 8, eventually ends up into code. So, we have, we're primarily developing the technical basis. So, we have an RFA that's focused primarily on that, that process.

RFA7 is an all-inclusive for training: technical exchanges, surveys, guidance documents, that sort of thing. So, again, most of these research focus areas come up with a guidance document or an implementation document. That's in RFA7.

And RFA8 covers advanced manufacturing. That's all your new technologies: your DED, your laser powder bed, all the new processes, other metallurgy. How can we implement those into building components and parts for the future?

Again, this is a mix of tactical, short-term, and fundamental research. Most of our fundamental research ends up being tactical very quickly, as you will see in some of these slides.

Next slide, please.

I just put in the next couple slides are just some highlights of a couple projects. I know a couple of us talked about AI and the machine learning. We're looking at adaptive feedback welding. This was driven by, you know, everything is blamed on welding. Welding is kind of everybody considers it an art sometimes. We're trying to take the art out of welding.

We're highly monitoring the welding process. And, again, this is just a visualization.

We basically digitized the process and are monitoring locations of the -- we're putting in the picture. If you can tell, the red is the tungsten from the gas tungsten arc welding. The brown is the molten weld puddle. The green is the solidified weld puddle behind the weld. And you can kind of see the joint geometry, the transition into the joint on the right of the weld.

We're monitoring all these locations and having it automatically correct itself as it welds down the joint.

Again, this is looking at acoustics, looking at vision, looking at vibration, a lot of the things that you can, you know, you often hear welders talk about the sound of welding. If it sounds good, it's welding good. So, we're looking at that aspect of it, too. So, heavily monitoring the welding process, and then implement -- and then implementing what's needed for that type of joint or that type of weld to make sure that it's defects free.

This was a fundamental research initially. We are now using portions of this program to implement a welding process that is -- somebody's waiting to get in, I think.

So, out at Hanford Site they're repackaging a lot of the liquid fuels out there. They're using some of this technology to actually monitor that welding system as they repackage those, those, that fuel.

Next slide, please.

Any questions there before I move on? No, it did not.

Again, this is, this is another one that's very closely following the workforce out there.

Yeah, there it did. Thank you.

In our industry, our outages have become very, very short. So, trying to, you know, keep those highly experienced repair people out there is very difficult. They're not willing to go somewhere for 2 weeks to do a repair anymore. So, trying to overcome that, you know, the monitoring processes may be very beneficial in the future.

Irradiated material weldability, this, this is a huge project. We started this project many years ago. You know, as plants are aging you have certain elements in the materials that we deal with that transmutate into helium. So, helium is a gas that's in the material. So, when you try to weld on that or repair that, that gas comes out and accumulates, and it causes pressure stresses inside the weld when it solidifies, and it pops open and it cracks.

So, we started a program with Oak Ridge National Labs in the LWRS program to actually irradiate material with known levels of helium, both the nickel and stainless steel alloy regimes, and then actually weld on it with known techniques that we can control the heat input and control the helium evolving out of the weld.

So, we did a very extensive program. We

were mimicking the Japanese work at GE back in the '80s and '90s, and taking that to the next level to see if we can extend the repairability of some of these alloys.

So, we've developed material. We've developed a facility at Oak Ridge and BWXT to actually weld on these materials. And we're monitoring those and characterizing those to determine how successful we were or does it need more work.

MEMBER PETTI: So, is the goal to try to get the time temperature so that the helium will come out of the weld?

MR. FREDERICK: Well, that's a very good question. Because one thing, you do want it to come out, then it's not a problem. Right?

MEMBER PETTI: Right.

MR. FREDERICK: But to get it all out is very difficult. You have to hold the puddle there.

So, we went to the route where we're actually trying to control the structural pile in the weld, for one, keeping the compression while we're welding so it pushes the helium back in, basically, pinches it back in. And then we can just keep it in there and weld it at a temperature that's very -- doesn't allow that helium to evolve to the boundaries as quickly.

So, we're trying to weld quicker, lower heat input, and maintain the stress profile as we weld. Those two, two basic things.

And we're also looking at there's sort of such a huge range of helium, in these materials, you can go from .1 ppm to 10, 15, 20, 30 ppm.

Down in this regime over here on the left side of the graphs here may be fairly weldable. So, we're trying to look for the most economical ways to fix that material compared to the stuff that's high helium where we may have to be very, you know, use more high tech processes to repair.

So, we're looking at the whole regime to make sure that we have the bases covered.

The pictures at the bottom, both the VIP and the MRP groups, both did the mapping of the plants to show where this could be an issue. So, in the internals areas and adjacent areas where the helium could be at a level where repairs could be hindered by this, by the helium.

CHAIR BALLINGER: I always thought that this was a heat effected zone problem.

MR. FREDERICK: It is.

CHAIR BALLINGER: Not a weld problem.

MR. FREDERICK: That's correct. Because the helium is in the base material.

CHAIR BALLINGER: So this is a weld problem?

MR. FREDERICK: Yeah. And the helium's coming, it's coming into the heat affected zone, or not really coming into it, it's actually going to one location in the green boundaries because you're allowing, the stressors are opening up the green boundaries and allowing the helium to get stuck into the green boundaries.

Next slide, please.

And if there are any areas you want me to slow down, then just let me know. I can talk for days on some of these, especially --

CHAIR BALLINGER: I don't think anybody in this room that's not -- that's around this table, except maybe Steve Schultz, knows what a temper bead is.

CHAIR BALLINGER: Okay, good. Well, good.

Well, the reason I only put this one slide in here on the temper bead because we were here a couple weeks ago talking about code cases. A lot of code cases related to welding on low alloy steels, vessel material are related to temper beads. Kind of not do post-weld heat treatment. We're trying to find ways to do the repair effectively, efficiently.

And, you know, through our research over the years temper bead has proved to be a almost better than -- not almost better, it is better than post-weld heat treatment. It gives you a material property that is improved over anything else we could have. You just have to do it correctly.

So, that's our, our research is basically allow you to monitor the technique, analyze the technique, qualify the technique, certify people to do this. And what we're looking at, what I put in this slide is really where we are now. Temper bead is acceptable in the U.S. We do it all the time. We've done it for 40 years maybe or better.

Internationally we have, we're still trying to introduce a lot of these techniques that we use here to those countries. So --

CHAIR BALLINGER: Well, what is a temper bead?

MR. FREDERICK: Oh, okay.

CHAIR BALLINGER: That's what we don't know. Okay.

MR. FREDERICK: Okay. Temper bead is when you do a very -- it's multi-pass welding, if I want to put it very simple. But you're using the subsequent weld beads to actually temper the previous weld bead.

So, you're actually basically putting it through a heat treat process every time you weld on it. You're just doing that in sequence where you know the properties. You know the depth of penetration of the heat. You know the properties of that, that area in the heat affected zone, from each weld bead as your sequencing there to create a tempered structure.

So, that's in the simplest terms I can put it. As Steve McCracken was here a couple weeks ago he probably had 100 slides on that, on temper bead he could have shared. And we have much -- I have a couple documents here that you're welcome to look at, too. But it's very sequenced process. Subsequent beads are tempering the previous beads.

MEMBER PETTI: So it can help those folks treat really thick sections that would be difficult to do.

MR. FREDERICK: Difficult range, yeah.

MEMBER PETTI: Impossible to --

MR. FREDERICK: Exactly, yeah.

Doing localized multiple heat treat is very difficult because you're affecting -- you're actually making it worse. You're affecting the areas around it. You're welding is already tempered and you've done many different things. So, now you're, now you're trying to correct all the, you know, evils you've done by welding on it.

But this process basically puts you in a state that's better than it was previously.

And that's what we're trying to show here. The newer, the newer, the future temper bead here, we're trying to make it now more economical to do, easier to qualify. We're using hardness protocol. We're starting to model the process. We're looking at all the low alloy steels around the world. We have a lot of vessels that were built in Russia and Germany that we're starting to take those low alloy steels and put them into our program to make sure that we're covering the bases for all low alloy steels around the world.

MEMBER PETTI: I'm seeing it in a lot of instrumentation now, modeled as --

MR. FREDERICK: Yes.

MEMBER PETTI: -- repairs.

MR. FREDERICK: Yes, exactly.

MEMBER PETTI: Yeah.

MR. FREDERICK: And it's usually just the first couple layers. And once you're done with that, you weld it out normally.

MEMBER PETTI: Yeah.

MR. FREDERICK: Next slide, please.

MEMBER PETTI: Is this the killer?

MR. FREDERICK: Nope. Not yet. It's coming.

Okay. Again, I just want to highlight a few of the areas that we're, that we worked fairly closely with ASME and the NRC on.

The canister mitigation repairs work that we're working on right now -- right now the status is that there's an inspection case out there that's available right now. We're working on the mitigation.

If, you know, again, we want to be prepared. Now that we have processes to monitor and inspect the spent fuel canisters, we want to make sure that if you find something we have to have a way to repair it. So, we're being proactive.

We're not expecting to find stuff. We are finding basic corrosion on the surface and stuff like that. But, again, you can't take that chance. So, we're looking at different ways to repair it or mitigate it for any cracking passes that are on the spent fuel canisters.

The first code case is primarily going to be on cold spray. It is a, it's related to the thermal spray. We're actually heating material and throwing it at the material. That's a more mechanical bonded process. You're putting material on material, and then it has a -- it is bonded to the surface more mechanically than metallurgically. But you're doing that to actually put a coating on there that's more corrosion resistant. And it's actually creating a compressive stress on the surface as well. So, you're, you're mitigating the potential development of cracking in the future.

So, I kind of wanted to highlight this one here because this, this is a pretty active code case right now. A lot of inspections are going on currently. So, we're just trying to, again, be proactive here.

We will move on to other processes. We wanted to pick one first to try to get it through ASME code as quick as possible and get that code case out there. So, we picked one process first.

This process has been vetted very heavily with the utilities. And I think the NRC has reviewed post-grade process. I think Songe has this approved on their essential process if they need to repair any of their canisters.

Next slide, please.

And, again, the last two bullets I have here, and I have a couple slides on our training stuff, but I wanted to highlight that, you know, I think Bob talked about it, the additive manufacturing, advanced manufacturing techniques. We're heavily engaged in that area, looking at anything that potentially could be used in the future.

Advanced manufacturing is not necessarily just for the future. It's for current operating plants as well: off fleet parts, replacement, that sort of thing.

So, and additive manufacturing has been used for a long time. So, I think this process is very valuable to the industry. You know, some of the areas that we're looking at is trying to eliminate welds, too. If you can make components without welds in there we'd have less inspection, less potential areas for defects and cracking in the future, or any kind of degradation.

As you noticed today and in most presentations, most degradation is associated with a weld in some manner.

And then RFA7 is our implementation. That's our guidance documents, our training documents, that sort of thing.

I know we talked about it a little bit earlier, the workforce. We are doing some supply chain workshops with the industry right now to help them look at potential solutions to the workforce issues in the future.

So, we are kind of engaged. I think, you know -- I don't think, I think Bob or someone made that comment earlier, it's not really EPRI's area to, you know, build the workforce for the industry. But it is a good area for us to help solve that with education and, you know, at least get people together to talk about it.

So, we have some workshops coming up in April. It's the second one of the supply chain workshops. It's workforce, fabrication, heat treat, it's the whole gamut of building the new plants.

So, let's go on. The next couple of slides are all related to training. And I'll go through those fairly quickly.

Again, I'd just emphasize on guidance documents, OE for shore bays. I kind of mentioned most of this stuff in the past. This is kind of the whole training initiative that we have at WRTC.

Next slide, please.

We started doing a number of things. Our members that are very engaged with repair and replacement need their professional development. So, we started doing training during our advisory meetings on an annual basis. Again, we take advantage of this.

We pick a topic that's very current. We get the utility members to actually help do the training. And then we do the training as well. So, we're learning, they're learning, and we're building a group of people that come together to do the training. So, I think it's helping develop our new early career people in the nuclear industry as well.

And just a list of different ones:

Repair and replacement training is our key, key one.

We do a lot of repair and replacement for ASME prior to outages at the utilities. So, they'll have us come in and do a 3-day training. It gets all their planners together, all their outage people, personnel together, and they, they come together and they do some training as a group. And they have more successful outages that way. They're all on the same page, they know what each other's jobs are.

Next one, please.

Again, we do regional type training. And then the only reason I put this in here, this is kind of tied to code cases. In some cases, 513 workshop, leak ceiling, temper bead, roll plate repair, so these are tied to code cases that are out there. So, they help to implement those.

And like I mentioned, repair and replacement training is the key one we do on a regular basis.

Next slide, please.

We have, as Bob mentioned, a lot of CBTs. WE started doing a lot of CBTs to make them more friendly. These are high, very high level for early career people. Then we're working for stages, early career to advanced career people to keep them educated in their fields.

Okay, so we have a full, full spectrum of training options.

Next slide, please.

Here's the problem, the problem child.

MEMBER HALNON: Greg, real quick on the previous. Don't go back.

Do you have any relationships with trade schools and academia at all?

MR. FREDERICK: Yes, we do. Yes, we do.

There's a number of colleges out there

that we work with to do different types of training. We work with some of the professors to help the implement or look at them.

But anything specific you were thinking of?

MEMBER HALNON: No. I was just thinking the trade schools mainly.

MR. FREDERICK: Yeah, yeah.

MEMBER HALNON: For some of these, when they learn how to be welders.

MR. FREDERICK: Yeah.

MEMBER HALNON: Get into the Section 9 hazard work.

MR. FREDERICK: Oh yeah. Our supply chain workshop we actually have, in our workforce development session in that workshop we have the Navy's coming in. We have American Welding Society coming in. We have trade schools coming in. All to give their perspective on the workforce in the future. And so, we're trying to have a pretty diverse section.

MEMBER HALNON: Okay.

MR. FREDERICK: So, yeah. So, hopefully we'll learn something.

I don't know if we're going to be able to play these are not, but these are just -- One thing I want to just highlight the last two slides here were just to highlight our capabilities in Charlotte. And so, if you can try to play these I'll kind of talk through them if you can.

If you can't, we'll just move on.

I see you're trying, aren't you?

Well, if you can see the pictures right in your slides. Our last tech meeting in Charlotte we basically brought in some stuff, very simple stuff if you think about it: laser ablation, laser cleaning.

If you think about where lasers have come over the last 20 years, very unreliable 20-plus years ago. The auto industry starting bringing in lasers to do automation.

And we might be successful here.

But they were fairly unreliable at the time.

So, oh, they're both running.

So, this is laser ablation here. This is just showing, you know, if you're going to do repair, for one, it has to be clean before you repair it. You have to inspect it, needs to be clean. Laser ablation, these are hand-held systems. You can go out there and just clean the system. You can buy these for home now. That's how far this technology has come.

So, and the one on the left is actually -- your left, too -- is the additive manufacturing, that's the DED, direct energy deposition welded valve body. So, that's all weld metal. So, we're trying to clean the surface of that weld metal so that you can -- you know, it was just more of a demonstration than anything else.

And the one on the right is just a pipe with scale and rust on it.

So, next slide, hopefully.

And these are no -- Oh, there is a video here. If you can play it, play it.

But the other thing, we tried to show leak ceiling. You know, and again, you'd think that's very simple.

You have to, most of the ASME code repairs require you to have a leak, leak-tight surface area before you repair it. It can't be leaking water. Has to be sealed.

So, we thought up techniques to help educate people how to go out in the field under high pressure temperature to seal cracks before they weld on it. So, we bring, we can bring them into the labs and actually do this.

So, we have a whole program to help people, mock-ups, and they can come in and actually demonstrate it. We can take this in the field. We've taken this to many utilities and actually had them use it on site before they went out in the field to do repairs.

This is just one of the things that we have in the EPRI offices in Charlotte.

And I believe that's it. Thank you for getting through the videos.

I think that's the last slide, was it?

Yeah. Well, thank you very much for your time today.

CHAIR BALLINGER: Okay. I don't think anybody's hand is up.

I don't think anybody's hand is up.

Do we need to go out for public comment?

MEMBER HALNON: Yes.

CHAIR BALLINGER: So, at this point we will ask if there's anybody out there listening, a member of the public that would like to make a comment, please state your name and then make your comment.

Star-6 if you're on a phone.

Okay. Not hearing any, any other questions from members? Okay. So, we're, are we at the end, Jim?

MR. CIRILLI: Yes, we are.

CHAIR BALLINGER: Okay. I mean, I would certainly like to thank you folks for coming here. It was not necessarily an obligation. But you guys are going to do this two more times. It's very informative, at least from my standpoint. And I hope it's informative for the other members. And they can speak for themselves. Okay.

MR. BLEY: Dennis. Dennis Bley.

I, too, want to thank you. This was really a good session all day. And I haven't been involved with these, the folks doing this kind of work with EPRI since everything was out west.

What you're up to these days is very impressive. If we could one day see your lab, I think that would be fantastic.

But thank you very much.

CHAIR BALLINGER: Okay. Any other comments from members?

I might add that it's after 5:00 o'clock in Charlotte. It's NASCAR country down there.

Walt?

MEMBER KIRCHNER: Thank you, Ron.

I just wanted to add in Dennis' comments that this was very informative. And thank all the presenters today. It gives us a lot to think about when we move on to advanced reactors.

This is an impressive set of programs to address known technology. It raises some interesting thoughts for how we go forward with advanced reactors that will see much more challenging and fluence conditions.

So, thank you.

CHAIR BALLINGER: I, for one, thought to learn something very new about the degradation matrices for the advanced reactors and the non-light-water reactors. So, I'm looking forward to that.

Other comments from members or consultants? And consultants.

Well, thank you very much, all your guys, for the long trip, even if it's just from Charlotte. But thank you again.

And so, we are adjourned.

(Whereupon, the above-entitled matter went off the record at 3:38 p.m.)

Executive Summary:
NEI 03-08 Materials Initiative

Jim Cirilli
EPRI, Senior Technical Executive

ACRS Fuels, Materials, and Structures SC Meeting
March 22, 2023

Underlying Premise and Challenge

Primary system materials integrity vital to plant performance and reliability

↓

Reactor components operate in a harsh environment (temperature, stress, radiation, etc.)

↓

Aging of plant system materials is complex and not always fully understood

↓

Routine surveillances can mitigate some of these factors; however, some failures can be expected

Challenge:

Find the next material vulnerability and address it before any failures occur

Historical Perspective

Late 1990s to Early 2000s

- BWRs managing IGSCC in reactor internals (BWRVIP) and piping (GL 88-01 and BWRVIP-75)
- PWRs begin identifying significant and costly materials degradation issues
  - $665M+ in unplanned repairs, replacements of components
  - Lost generation and daily replacement power costs ($1M/day)
  - Increased dose exposure
  - Increased regulatory agency involvement and oversight
  - Quality of life of utility workforce

Leaking PWR CRDM Head Penetrations

Indian Point SG tube leak (February 2000)

Davis – Besse CRDM penetration leakage/head wastage (March 2002)

V.C. Summer Crack in RCS hot leg nozzle to pipe weld (Fall 2000)

Industry Response

- In 2002, in the face of significant materials issues, the Nuclear Energy Institute (NEI) Executive Committee directed the industry to develop a strategy to anticipate materials issues including what will fail, when it will fail, and what is susceptible
- Materials Assessment Working Group (MAWG) was formed with representatives from all industry groups dealing with materials issues to assess existing materials programs
  - Scope
    - Primary pressure boundary components in BWRs and PWRs
    - Materials issues related to nuclear fuels
    - NDE
    - Chemistry/corrosion control programs

NEI 03-08: Guideline for the Management of Materials Issues

- Formal agreement among the utility Chief Nuclear Officers (CNOs) that form the Nuclear Strategic Issues Advisory Committee (NSIAC) to follow a defined policy
- Unanimous approval May 2003
- Initiative provides for:
  - *Proactive management of materials aging*
  - *Integration, coordination and prioritization of industry work on materials issues*
  - *Funding provision for high priority, emergent and long-term issues*
  - *Consistent and timely implementation of guidelines*
  - *Oversight of industry material activities*
- Initiative documented in ***"NEI 03-08 – Guideline for Management of Materials Issues"***
  - Treated as if it were a regulatory commitment
  - Current version is Revision 4 (October 2020)

Proactive – Engaged – Safety Focused

NEI 03-08 Scope and Issue Programs

- Scope
  - Reactor internals
  - Primary system pressure boundary components
  - Related NDE, chemistry and corrosion controls
- Materials Issue Programs (IPs)
  - EPRI BWR Vessel & Internals Project (BWRVIP)
  - EPRI Materials Reliability Program (MRP)
  - EPRI Steam Generator Management Program (SGMP)
  - EPRI Nondestructive Examination Program (NDE)
  - EPRI Water Chemistry Control Program (WCC)
  - PWR Owners Group Materials Committee (PWROG MSC)

NEI 03-08 is a governance document for the Materials Sector

NEI 03-08 Expectations

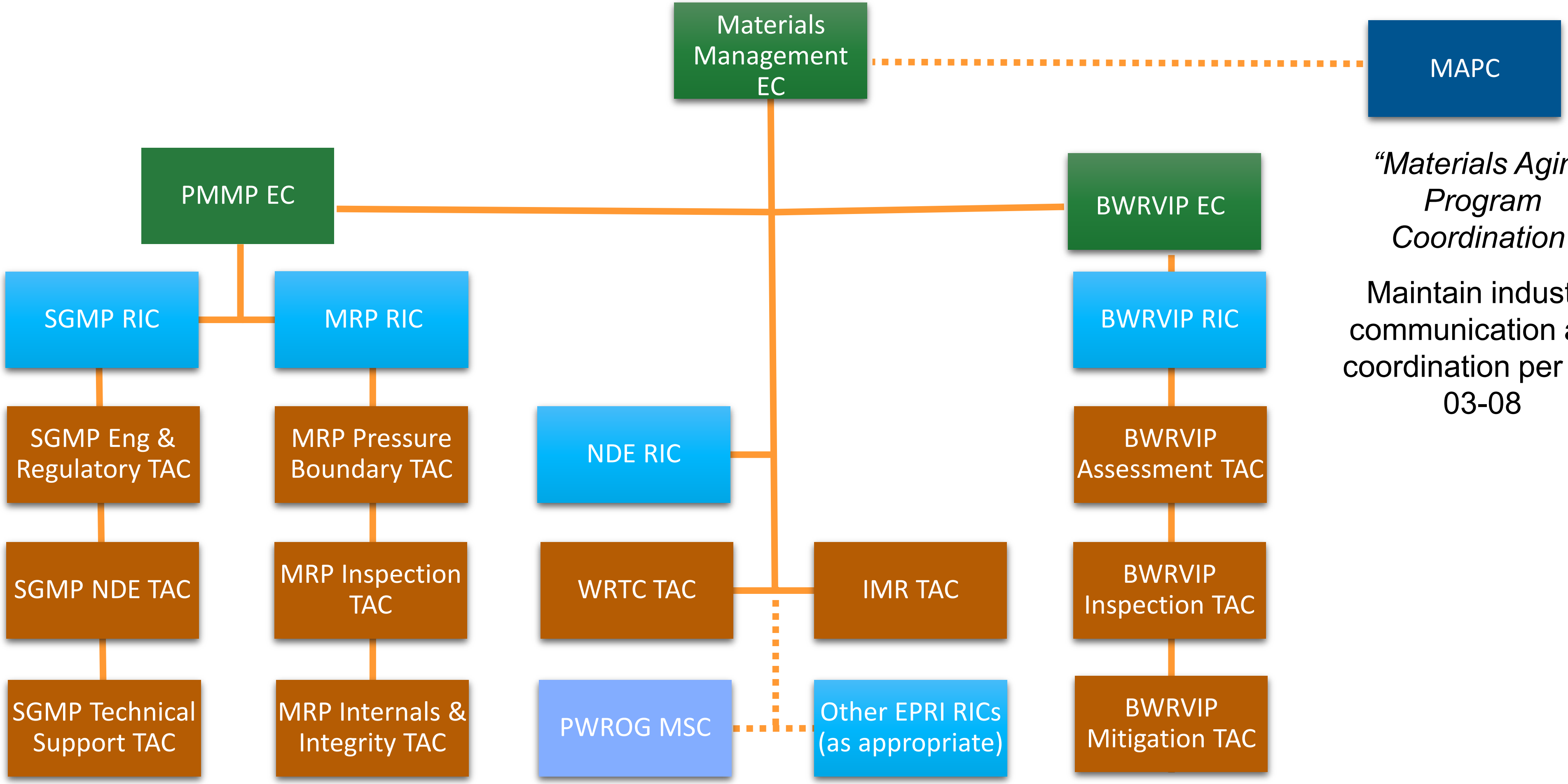
- Utility Responsibilities
  - Maintain a Reactor Coolant System Materials Degradation Management Program
  - Implement required Issue Program guidance
  - Participate in Issue Programs
  - Communicate materials Operating Experience
- Issue Program Responsibilities
  - Identify, prioritize, and resolve issues
  - Communicate operating experience
  - Develop guidance
  - Manage regulatory interface on generic issues
  - Manage process to address emergent materials issues

NEI 03-08 Accomplishments

- Integrated industry strategic plan for materials
- Achieved a high level of industry integration, coordination, alignment, and communication on material issues
- Established a process for prioritizing projects, budgets, and planning
- Predictable funding for materials R&D
- Engaged INPO as an active participant (Material Review Visits)
- Defined expectations and protocols for industry actions upon discovery of an emergent issue
- Established consistent process for deviations and communication with NRC
- Executive level interactions between industry and senior NRC management
- Successful at closing materials issues and gaps (MDM/IMT)
- Fewer unexpected materials related transients

Success due to industry engagement and commitment

Materials Organizational Structure



"Materials Aging Program Coordination"

Maintain industry communication and coordination per NEI 03-08


Together…Shaping the Future of Energy®

EPRI Materials Degradation Matrix (MDM) and Issue Management Tables (IMT)

Jean Smith, PhD PE
EPRI, Program Manager

ACRS Fuels, Materials, and Structures SC Meeting
March 22, 2023

Agenda

- EPRI Materials Aging Management Cycle
- Materials Degradation Matrix
- Issue Management Tables
- MDM Process for Advanced Non-Light Water Reactors
- Next Steps and References

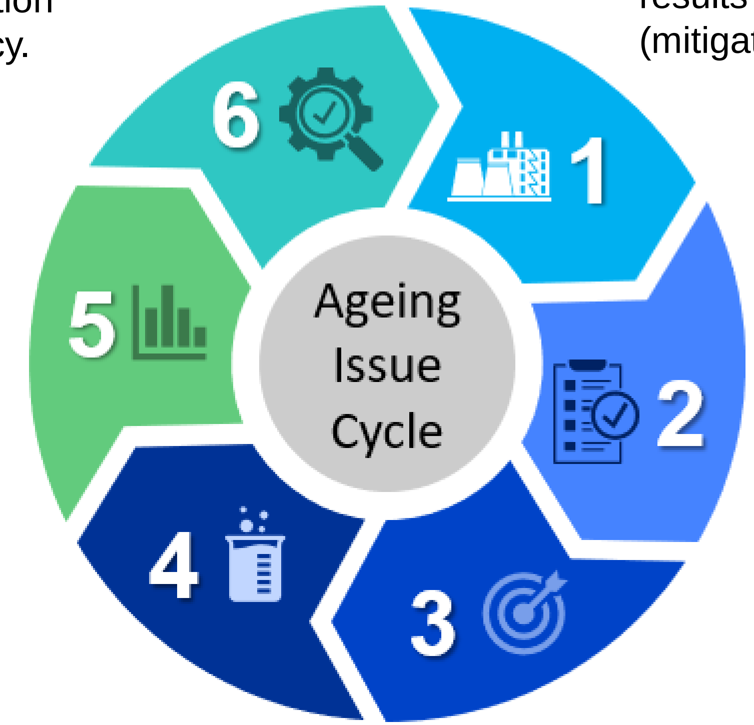
EPRI Materials Ageing Management Cycle

6. Optimize Inspections

Increased confidence in ageing management strategies leads to optimized inspection requirements with respect to scope and frequency.

1. Collect Operating Experience

EPRI SMEs collect data from field reports and inspection results and assess the efficacy of corrective actions (mitigation, repair, replacement).



5. Calibrate Models

Improve accuracy and technical robustness of databases that provide inputs to materials models; calibrate conservatism applied to ageing management strategies.

2. Review Research Results

Updated research results from EPRI programs, technical literature, and conferences are reviewed by EPRI SMEs.

Materials Degradation Matrix (MDM) Revision 4 (3002013781; May 2018)

4. Address High-Priority Gaps

Conduct research on representative materials, perform simulations, develop new models to address high-priority assessment and degradation mechanism gaps.

3. Evaluate Technical Gaps

Review gaps from previous IMT (close, keep open, re-rank); define new gaps based on OE; prioritize gaps with utility members.

BWR Issue Management Tables BWRVIP-167 Rev. 4 (3002018319; June 2020)
PWR Issue Management Tables MRP-205 Rev. 4 (3002018255; September 2020)
VVER Issue Management Tables MRP-471 (3002021033; September 2021)

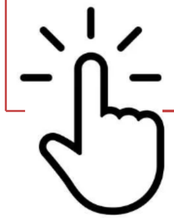
Materials Degradation Matrix (MDM)

- The EPRI Materials Degradation Matrix summarizes the state of industry knowledge regarding the degradation mechanisms and related research activities
- Degradation is defined for normal operating conditions
- Color codes:
  - Green → well understood, no R&D necessary.
  - Yellow → sufficient R&D in progress to address gaps in reasonable timeframe.
  - Orange → insufficient R&D ongoing/planned to address gaps in reasonable timeframe.
  - Blue → insufficient data exists to establish degradation mode applicability.

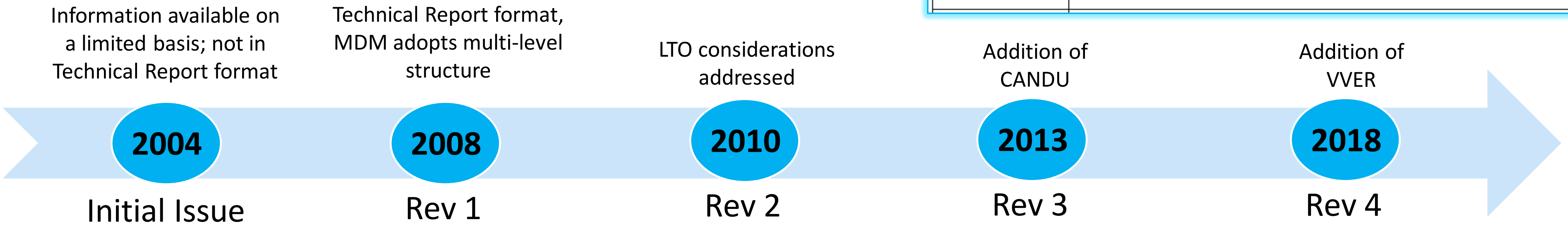
PWR Primary Pressure Boundary

Table 4-1
PWR Primary Pressure Boundary (1)

MATERIAL	DEGRADATION MODE														
	Corrosion				Wear	SCC		Fatigue		Reduction in Fract Properties		Irradiation Effects			
	Wstg.	Pitting	FAC	Foul	Wear	IG / TG	IA	HCF	EAF	Th	Env	Emb	VS	IC / SR
C&LAS: Base Metal & HAZ	Y p1-1a	N	N	N	N	Y p1-6a	Y p1-7a	N	Y p1-9a	? p1-10a	Y p1-11a	Y p1-12a	N	N
C&LAS: Welds	Y p1-1b	N	N	N	N	Y p1-6b	Y p1-7b	N	Y p1-9b	? p1-10b	Y p1-11b	Y p1-12b	N	N
SS: 300 Series SS Base Metal & HAZ	N	Y p1-2c	N	N	N	Y p1-6c	N	Y p1-8c	Y p1-9c	N	Y p1-11c	N	N	N
SS: 300 Series SS Welds & Clad	N	Y p1-2d	N	N	N	Y p1-6d	N	Y p1-8d	Y p1-9d	Y p1-10d	Y p1-11d	Y p1-12d	N	N
Cast Austenitic Stainless Steel	N	N	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]



NOTE ID	EXPLANATORY NOTE
	PWR PRIMARY PRESSURE BOUNDARY AND STEAM GENERATOR DIVIDER PLATE
p1-1a p1-1b	Gaps in the channel head cladding can permit low low-alloy steel to come into contact with primary water. Significant corrosion could potentially occur as a result of exposure to oxidizing conditions, occurring most likely after shutdown and draining activities due to concentration of a puddle of primary water by evaporation. There is a general understanding of how corrosion can progress and the overall timeframe. There are no fundamental R&D gaps. Any gaps related to management of this issue should be addressed within the PWR IMT report. [R&D Status = GREEN] **References:** Other: [4-2]



MDM Example
PWR Steam Generator Tubing, Tube Plugs, & Tubesheet Welds

Table 4-3
PWR Steam Generator Tubing, Tube Plugs & Tubesheet Welds

MATERIAL	DEGRADATION MODE										
	Corrosion				Wear	SCC		Fatigue		Reduction in Fract Properties	
	Wstg.	Pitting	FAC	Foul	Wear	PS (ID)	SS (OD)	HCF	EAF	Th	Env
TUBES											
Ni-Alloy: 600TT	Y p3-1a	N	N	Y p3-4a	Y p3-5a	Y p3-6a	Y p3-7a	Y p3-8a	Y p3-9a	N	Y p3-11a
Ni-Alloy: 690TT	Y p3-1b	N	N	Y p3-4b	Y p3-5b	Y p3-6b	N	Y p3-8b	Y p3-9b	N	Y p3-11b
SS: Alloy 800	Most use of Alloy 800 steam generator tubing is associated with CANDUs. Refer to the CANDU results section (Section 7) for Alloy 800 tubing results.										
TUBE PLUGS & TUBESHEET WELDS											
Ni-Alloy: Tube Plugs	N	N	N	N	N	N	Y p3-7d	N	Y p3-9d	N	Y p3-11d
Ni-Alloy: Alloy 52 / 82 Welds	N	N	N	N	N	N	Y p3-7e	N	Y p3-9e	N	Y p3-11e

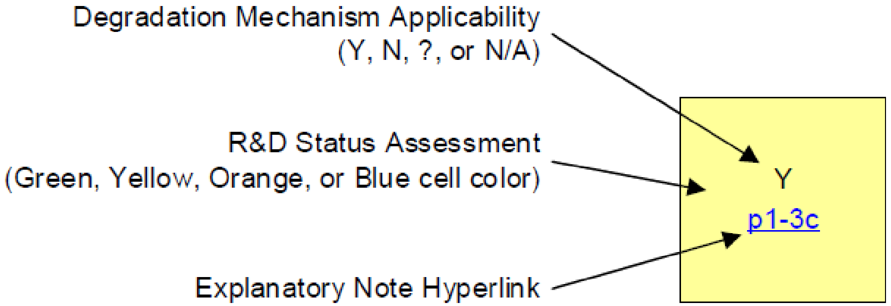


Table 4-7
PWR Systems Explanatory Notes

	STEAM GENERATOR TUBING
p3-1a p3-1b	Wastage of thermally-treated Alloy 600 or Alloy 690 tubing is assumed to be possible in principle, but there is not any field experience to date. Thermally-treated A600 has the same chemical composition as mill annealed Alloy 600 where wastage did occur for some older steam generators. In recent years, implementation of improved water chemistry controls has prevented significant wastage of thermally-treated Alloy 600 or Alloy 690 tubing. [R&D Status = GREEN] References: EPRI: 1024992, 3002012420 (Materials Handbook)
NOTE ID	**EXPLANATORY NOTE**
p3-4a p3-4b p3-8a p3-8b	Fouling of steam generator tubes, particularly of tube-to-broached tube support openings, is an issue of concern. Worldwide, a number of steam generators have experienced heavy build-up of deposits which reduced or blocked water / steam flow through the broached quatrefoil openings (or trefoil in OTSGs). Fouling and flow blockage occurs preferentially at specific locations inside the steam generator. As a result, additional flow can be forced into the open lane at the center of some tube bundle configurations resulting in flow well above design values. Blockage can also result in tubes being effectively fixed to a tube support plate allowing for unusual modes of vibration subsequently leading to tubing fluid-elastic instability and high-cycle fatigue cracking of the tube. Additional research is needed to determine the level of deposit buildup needed to fix the tube in a quatrefoil tube support and flow fields involved. Research remains in progress to fully characterize this fouling phenomenon and research along multiple paths is being pursued. First, better understanding of flow fields and the effect of blockages through development of advanced computational fluid dynamics simulation is necessary to predict when flow patterns could induce potentially high degradation rates. Second, work to better understand the phenomenon of fluid-elastic instability is ongoing to better define the margin to the onset of this important phenomenon (see task p3-5a). Third, work to better control iron transport and deposit buildup is ongoing to help reduce the growth of fouling and reduce deposit buildup rates. [R&D Status = YELLOW] **References:** EPRI: 1018344, 1018888, 1020643, 1020994, 1022667, 1022824, 1024837, 1025127, 1025129, 3002005515, 1025317 Other: [4-43], [4-44], [4-45], [4-46]

EPRI Issue Management Tables (IMTs)

- The EPRI Issue Management Tables proactively identify and prioritize the various states of materials degradation and provide the capability to manage the R&D gaps.
- Primary side pressure boundary components, reactor internals, SG tubing and associated secondary side components.
- Normal operating conditions.

- R&D Gap Categories:
  - **Degradation Mechanism (DM) Understanding Gaps** → R&D needed to understand.
  - **Assessment (AS) Gaps** → Mechanism understood. R&D needed to address impact and/or to characterize and manage.
  - **Mitigation (MT) Gaps** → R&D needed to invent / demonstrate mitigation technology.
  - **Inspection & Evaluation (I&E) Gaps** → Inspection guidance, NDE qual, development/improvement of NDE capabilities.
  - **Repair / Replacement (RR) Gaps** → development or verification of repair techniques.

PWR IMT DM Gaps

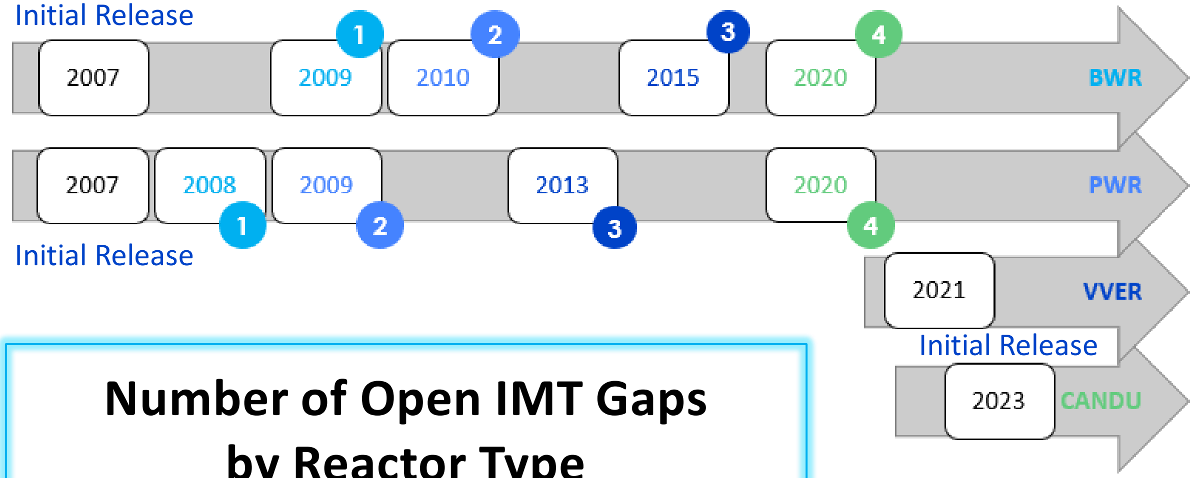
Table 3-1
Summary of R&D Gaps and Gap Priorities

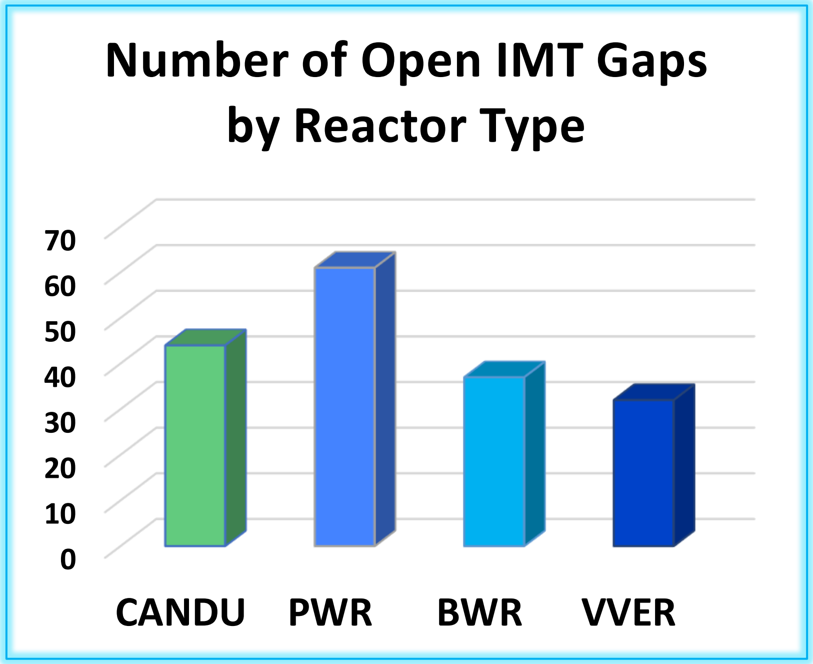
Gap ID	Description	R3 Priority	R4 Priority
Degradation Mechanism (DM) Gaps Assessment (AS) Gaps			
P-DM-09	Environment Effects on Fracture	Med	Low
P-DM-10	Therm... Embrittleme... Pressurizer ...mpera...		
P-DM-11	SCC of Thermally Ag...		
P-DM-12	Increased Fastener S...		
P-DM-13	Long-Term SCC Sus...		
P-DM-15	Thermal Embrittleme...		
P-DM-16	Thermal Embrittleme... Support Plates)		

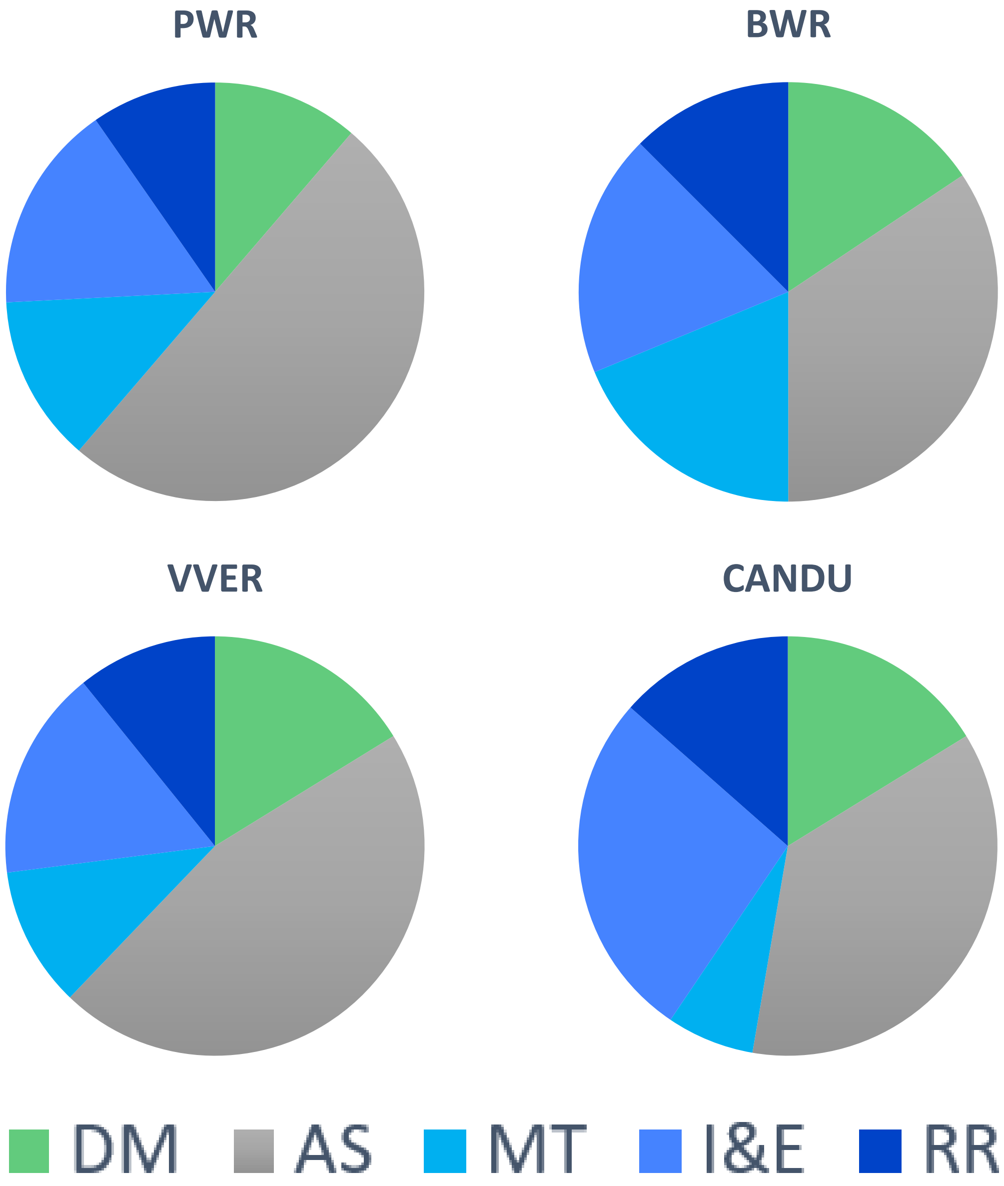
Table 3-2
Degradation Mechanism Understanding (DM) R&D Gaps

R&D Gap Description	Results Data
P-DM-09 – Environmental Effects on Fracture **Issue:** Recent testing indicates that primary systems materials can have lower fracture resistance (J-R tearing resistance) when tested in coolant than when tested in air. Although there is an increasing body of data that can be used to quantify the effect, the factors influencing this phenomenon and the significance of this effect for PWR primary system components remain incompletely understood. **Description:** Substantial reductions in the J-R fracture resistance of some structural materials have been observed by various investigators. One specific form of this reduction is low temperature crack propagation which occurs at relatively low temperatures (< 150 °C). Environmental effects on fracture are most marked when this phenomenon occurs. The "Low Temperature Crack Propagation" phenomenon has been shown by laboratory testing to be valid for several materials (CASS, Alloy 182, and X-750) deployed in PWRs. More testing is needed to determine for which materials' low temperature effects are most significant and to specific ranges of temperatures for which it occurs for those materials. (See P-AS-40) Effects observed at operating temperature are lower in magnitude than those observed at low temperature, some effect of environment on J-R response is likely to persist at operating temperature, where the majority of service time is accumulated and higher loads are experienced. There is general consensus that the effect is a hydrogen-induced phenomenon. However, uncertainties remain regarding how hydrogen fugacity in the environment, the diffusivity of hydrogen within the metal, and the interaction of hydrogen with other parameters (e.g., temperature and material loading rate) affect the observed phenomena. Since the effect of hydrogen increases with material yield strength, the effect of environments is likely to be more marked on cold work and irradiation hardened materials. Synergism of this phenomenon with other forms of cracking including SCC and corrosion fatigue must be taken into account. This gap can be applied to all materials wetted by the primary coolant system. Since closure of this gap would involve complete characterization of fracture behavior of all materials the gap remains open. However, because understanding developed in recent years the current priority level is reassigned to "Low". [NOTE: With regard to observations of rapid fracture occurring under rising K conditions, similar testing in air concluded that plastic instability resulting from mechanical overload conditions was the primary factor in the observations associated with stainless steels and nickel-base welds. No evidence of an effect of environmental was observed.] **References:** MDM (Notes p1-11a, p1-11c, p1-11d, p1-11e, p1-11f, p1-11h, p2-11a, p2-11b, p2-11f, p2-11h, p3-11a) EPRI 1019030, 1020957, MRP-209, MRP-213, MRP-293, MRP-431	**Status:** Open **Priority:** R4 (2020) Low R3 (2013) Medium R2 (2010) Medium R1 (2008) Medium **Responsibility:** MRP

IMT Revisions and Open Gaps







Example: CANDU IMT Development

Development Approach

- Similar to the development of VVER IMTs, existing IMTs can provide a starting point
- CANDU systems to be addressed by IMTs

Draw from PWR IMTs

- SGs and secondary side components & piping
- Primary heat transport system

CANDU specific

- Fuel Channels
- Calandria vessel & moderator system

Potential CANDU High-Priority Gaps

- Effect of irradiation on the mechanical property evolution for Type 403 stainless steel end fittings (AS).
- Effect of irradiation on the fracture toughness of calandria vessel welds (Type 304L/308L SS) for long-term operation up to 100 EFPY (AS).
- Susceptibility of the calandria vessel to irradiation-assisted stress corrosion cracking for long-term operation up to 100 EFPY (AS).
- Effect of deuterium pick-up on Zr-Nb-Cu fuel channer spacers (AS).
- Mitigation of deuterium ingress at the pressure tube rolled joints for long-term operation up to 300K EFPH (MT).
- SG tube damage due to loose parts or foreign objects (AS).

MDM Process of ANLWRs

Materials Based

Material Property Assessment and Data Gap Analysis for the Prospective Materials for Molten Salt Reactors
3002010726

Material Property Assessment and Data Gap Analysis for Sodium-Cooled Fast Reactors
3002016949

Material Property Assessment and Data Gap Analysis for the Prospective Materials for Very High Temperature Reactors and Gas-Cooled Fast Reactors
3002015815

Materials Property Assessment and Gap Analysis for Lead-Cooled Fast Reactors
3002016950

Advanced Reactor Materials Development Roadmap

Addresses extension of ASME Code property data and mechanical, corrosion, and irradiation property data

3002022979 (2021)

Materials Degradation Matrix for Advanced Non-Light Water Reactors

(to be developed; 2023)

Component Based

Issue Management Tables for Molten Salt Reactors

Issue Management Tables for Sodium-Cooled Fast Reactors

Issue Management Tables for VHTRs and Gas-Cooled Fast Reactors

Issue Management Tables for Lead-Cooled Fast Reactors

Next Steps and References

- Materials Degradation Matrix Revision 5
  - Updates based on operating experience and research results
  - Publication 4Q2023
- Issue Management Tables
  - CANDU IMT initial publication in 2023
  - PWR and BWR IMT Revision 5 in 2024
  - VVER IMT Revision 1 tbd

- Advanced Non-Light Water Reactor Materials Degradation Matrix
  - Currently under development
  - IMTs for leading plant designs to follow

- Light Water Reactor - Small Modular Reactors (LWR SMR) Materials Degradation Matrix
  - Degradation mechanisms to be developed subsequent to MDM Rev. 5
  - Specific reactor design tables to be addressed

The EPRI MDM and IMTs can be downloaded at www.epri.com using the following product ID numbers and/or links:

- Materials Degradation Matrix (MDM): Product ID 300201378
  - https://www.epri.com/research/products/000000003002013781
- BWR Issue Management Tables: Product ID 3002018319
  - https://www.epri.com/research/products/000000003002018319
- PWR Issue Management Tables: Product ID 3002018255
  - https://www.epri.com/research/products/000000003002018255
- VVER Issue Management Tables: Product ID 3002021033
  - https://www.epri.com/research/products/000000003002021033


Together…Shaping the Future of Energy®

BWR Reactor Vessel and Internals Project (BWRVIP)

Recent Efforts on Management of Materials Aging Issues

Nathan A. Palm, PE
EPRI, Sr. Program Manager

ACRS Fuels, Materials, and Structures SC Meeting
March 22, 2023

Contents

- BWRVIP
  - Background and Objectives
  - Members
  - Organization and Committee Responsibilities
- Recent BWR Materials Aging Management Highlights
  - Reactor Vessel Integrated Surveillance Program (ISP) for Second License Renewal (SLR)
  - Aging Management Approach for SLR
  - Irradiated Stainless Steel Fracture Toughness Guidance Update and Impact
  - Status of Mitigation, Validation Efforts and Platinum Deposition Modeling
  - Inspection Data Collection and Inspection and Evaluation Guidance Optimization

BWRVIP Background and Objectives

- Background
  - Intergranular Stress Corrosion Cracking (IGSCC) in austenitic piping was a major issue for Boiling Water Reactors (BWRs) in the 1980s – susceptibility of reactor internals to IGSCC was also recognized
  - Shroud cracking in 1993-1994 confirmed that IGSCC of internals is a significant issue for BWRs
  - BWR utility executives formed the BWRVIP in mid-1994
- Objectives
  - Lead industry toward proactive generic resolution of vessel and internals material condition issues with generic, cost-effective strategies
  - Identify or develop generic, cost-effective strategies
  - Serve as a focal point for the regulatory interface with the industry in BWR vessel and internals material condition issues
  - Share information among members to obtain useful data from many sources

2023 BWRVIP Member Utilities

U. S.

- Constellation
- DTE Energy
- Duke Energy
- Energy Northwest
- Entergy
- Energy Harbor
- NPPD
- PSEG Nuclear
- Southern Nuclear Company
- Talen Energy
- Tennessee Valley Authority
- Xcel Energy

Intl

- Chubu Electric Power Company – Japan
- Chugoku Electric Power Company – Japan
- Comision Federal de Electricidad – Mexico
- Forsmarks Kraftgrupp AB – Sweden
- Iberdrola Generation – Spain
- JAPC – Japan
- Kernkraftwerk Leibstadt – Switzerland
- OKG Aktiebolag – Sweden
- Tokyo Electric Power Company – Japan

BWRVIP Organization

Executive Committee

Marty Bonifanti, Constellation (Chair)

Ken Knaide, PSEG (Vice Chair)

Nathan Palm, EPRI (Program Manager)

Executive Oversight Committee

Marty Bonifanti, Constellation (EC Chair)

Ken Knaide, PSEG (AC/IC Exec Sponsor)

Josh Ohotto (MC Exec Sponsor)

Andrew Barritt, KKL (International Sponsor)

Troy Barker, NPPD (EOC at large)

Research Integration Committee

Steve Richter, Energy Northwest (Chair)

Donnamarie Bush, PSEG (Vice Chair)

Wynter McGruder, EPRI (Task Manager)

Denver Atwood, Southern (BWROG Chair)

Assessment Committee

Donnamarie Bush, PSEG (Technical Chair)

Carl Rosenwald, DTE Energy (Vice Chair)

Todd Sherman, Entergy (Vice Chair)

Bob Carter, EPRI (Task Manager)

Inspection Committee

Christian McKean, Constellation (Technical Chair)

Shane Charbonnet, NPPD (Vice Chair)

Bob Grizzi, EPRI (Task Manager)

Mitigation Committee

Becky Nealis, Constellation (Technical Chair)

Taryn Barber, Xcel Energy (Vice Chair)

Michelle Mura, EPRI (Task Manager)

BWRVIP Technical Committees and Responsibilities

Assessment	What needs to be inspected, when it needs to be inspected, inspection options, how to disposition observed degradation
	What repair/replacement techniques are available and what are the associated requirements that must be met
Inspection	How to inspect, what equipment and techniques are available, what are the associated uncertainties
Mitigation	How can SCC degradation be prevented or reduced

Reactor Vessel Integrated Surveillance Program (ISP) for Second License Renewal (SLR)

Background

- Since 2010, the U.S. BWR fleet has used an NRC approved integrated surveillance program (ISP) to monitor RPV embrittlement and satisfy 10 CFR 50 Appendix H requirements
- The BWRVIP integrated surveillance program (ISP) combines surveillance materials from across the U.S. BWR fleet, including the already completed BWROG supplemental surveillance program (SSP) to:
  - Resolve fleet wide limitations in the original BWR surveillance programs
  - Provide a more appropriate representation of the limiting beltline materials for each plant
  - Optimize the total number of capsules to be tested by the BWR fleet
- NRC-approved program provides for 60-year operation
  - 13 plants serve as hosts
  - Testing deferred for 21 plants, some of which serve as potential contingencies (to cover situations where a host plant shuts down)
  - 15 representative plate heats and 15 representative weld heats provide data for target (limiting) materials in each member plant reactor vessel

Extension for SLR

- An extension to the ISP for SLR (60 to 80 years) has been developed and approved by the NRC in BWRVIP-321-A
- The fundamental approach used for the 60-to-80-year period is the same as for the original 60-year program
- Some surveillance data already irradiated and tested under the ISP is at high enough fluence to support 80-year RPV operation (7 representative materials)
- Using specimen reconstitution, 80-year fluence surveillance data will be obtained for those materials in the ISP where 80-year fluence data does not already exist (23 representative materials)
- A specialized surveillance capsule holder will position the capsule several inches from the outside diameter of the core shroud to obtain irradiation conditions that are accelerated as compared to normal BWR capsule conditions but still within the range of BWR RPV conditions
- Capsules are scheduled to be installed in late 2023 and withdrawn in 2035

Aging Management Approach for SLR

Current Status

- BWRVIP guidance continues to be effective in proactively detecting and addressing age-related degradation
- Most of the elements of an effective AMP are not impacted by consideration of longer operating periods and need not be revisited to address operation beyond 60 years
  - Elements that are not impacted include program scope, detection methods / NDE standards, and administrative controls / corrective actions
- Review of BWR operating experience does indicate any adverse trends
  - Rather, the main observation is that most safety-significant degradation occurred relatively early in life with little evidence of new cracking in recent years
- BWR fleet experience is actively monitored and evaluated by the BWRVIP and guidance is revised as appropriate to address new operating experience
- Revisions of aging management guidance needed to address operation beyond 60 years are limited to evaluation elements that include ”time-dependent” factors

BWRVIP Aging Management – Approach to SLR

- BWRVIP aging management guidance was reviewed to identify "time-dependent" factors that could impact guidance adequacy or applicability
  - Factors associated with age-related degradation that directly or indirectly correlate with total accumulated operating time (e.g., neutron fluence, fatigue cycles)
- Unless impacted by time-dependent factors, guidance remains adequate to manage the effects of aging
  - The BWRVIP program includes activities to assess operating experience and new R&D results. Guidance is updated as needed using NEI 03-08 process.
- Whenever possible, aging management guidance implementation should be linked to engineering-based parameters related to onset / progression of age-related degradation
  - Contained in the underlying analytical work forming the technical basis for AMP implementation
  - NOT based on any specific operating period
  - Each owner / licensee confirms that their plant satisfies any conditions for use
    (This approach is reasonable given the substantial variation in plant operating conditions and the uncertain makeup of the fleet of BWRs that will pursue SLR)

BWRVIP Reports Applicable to Operation Beyond 60 Years

- BWRVIP-315, Reactor Internals Aging Management Evaluation for Extended Operations
  - Documents a technical evaluation of the adequacy of the BWRVIP guidance to continue managing age-related degradation of BWR reactor internals for operating periods exceeding 60 years
  - Identifies revisions to BWRVIP guidance for reactor internals needed to address extended operations (*primarily revisions to ensure the effects of neutron fluence on component integrity evaluation methods are appropriately defined*)
- BWRVIP-329, Probabilistic Fracture Mechanics Analysis of BWR RPV Welds to Address Extended Operations
  - Provides a technical basis for continued relief from ASME Section XI RPV weld examination requirements. Criteria for use are specified in terms of end-of-life reference temperature values.
- BWRVIP-316, Reactor Vessel Aging Management Evaluation for Extended Operations
  - Similar to BWRVIP-315, but addresses the RPV vs. reactor internals

BWRVIP-315 remains under review by NRC (as of March 9, 2023)

BWRVIP-329 has been approved by NRC

BWRVIP-316 will be completed and submitted to NRC for review and approval in 2023

Irradiated Stainless Steel Fracture Toughness Guidance Update and Impact

Background

- Beginning in the mid-to-late 1990's, data from experiments conducted on irradiated stainless steels were collected and evaluated by BWRVIP to determine correlations between fracture toughness and neutron fluence for conditions representative of BWR operating conditions
  - These correlations were essential for dispositioning flaws in irradiated core shroud welds
- Recent testing of harvested materials from Zorita and Barsebäck showed lower than anticipated fracture toughness for weld metal, and indicated a potential non-conservatism in the BWRVIP fracture toughness correlations (published in BWRVIP-100, Rev. 1-A)
  - Resulted in a 10 CFR Part 21 transfer of information notice to all BWRVIP members in February 2021
  - Several meetings have taken place between BWRVIP and NRC staff to keep NRC informed of BWRVIP efforts and progress to address the issue

Current Status

- Revised fracture toughness vs fluence correlations for weld and base metal have been developed and will be submitted for NRC review and approval in mid-2023
  - Lower bound fracture toughness for LEFM remains the same for weld and base metal but is reached at a slightly lower fluence for weld
  - Limit Load is no longer the governing evaluation method for lower fluences
  - EPFM needs to be considered in conjunction with limit load up to the lower bound fracture toughness fluence threshold applicable for weld and base metal
- BWRVIP has developed a plan for addressing impacted inspection and evaluation guidelines
  - A generic flaw evaluation guideline will be developed to supersede guidance in individual component reports
  - Interim guidance may be issued on core shroud inspection intervals
  - Actions planned to be complete by end of 2023

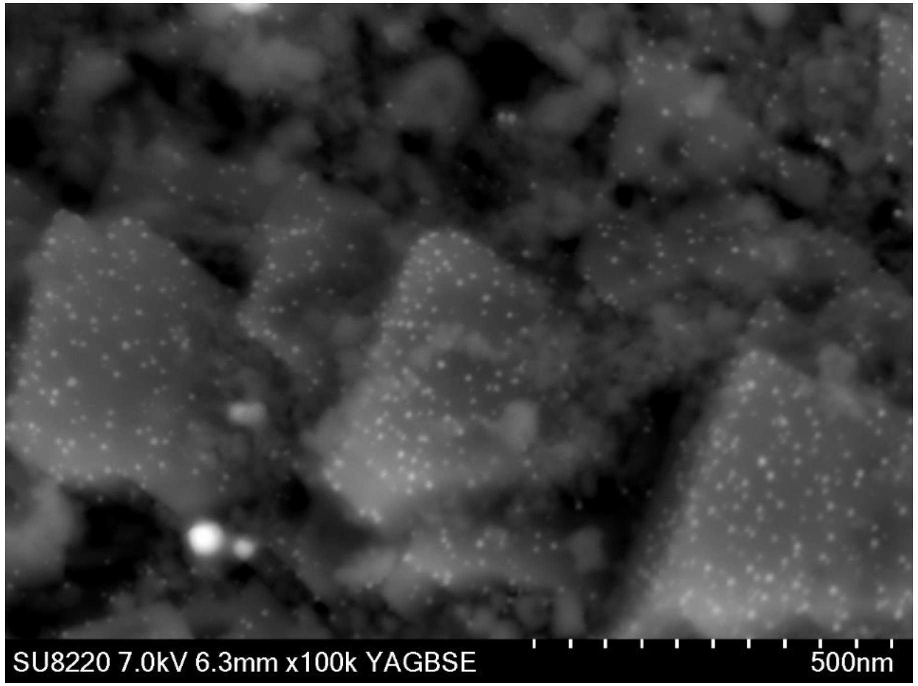
Status of Mitigation, Validation Efforts and Platinum Deposition Modeling

Background

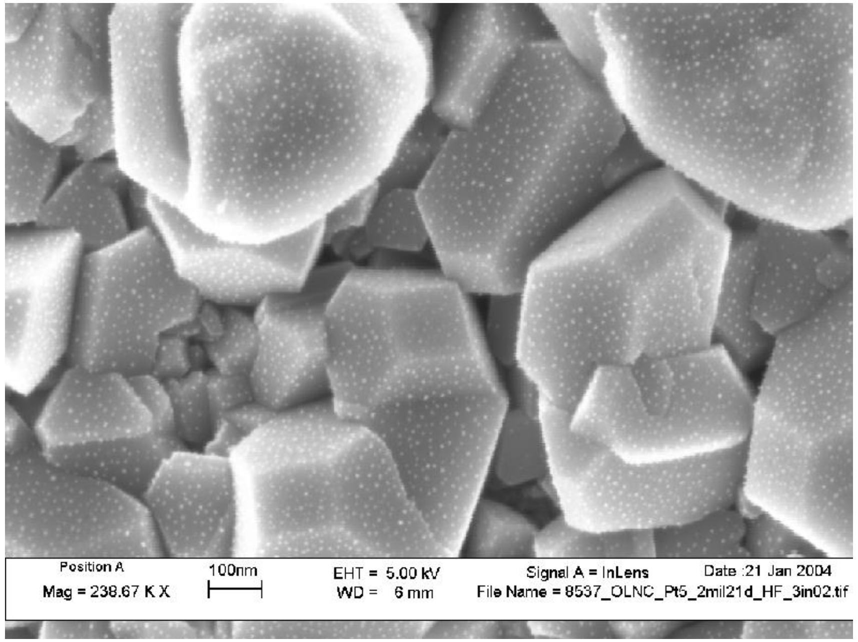
- On-Line NobleChem™ (OLNC) is an advanced IGSCC mitigation method that has been adopted by most of the operating BWRs in the U.S.
- The effectiveness of this method relies on the deposition of platinum (Pt) nanoparticles on reactor internal surfaces which catalyze the recombination of hydrogen and oxidants, thus lowering the electrochemical corrosion potential (ECP) at the surfaces to levels at which crack initiation and extension rates of existing cracks are mitigated.
- Currently, plants monitor ECP to ensure that adequate Pt is available to mitigate cracking.
- BWRVIP research is ongoing to validate that sufficient Pt catalyst is deposited on reactor internal surfaces and adequately distributed with the expected particle size, density, and spacing to reduce oxidants at surfaces to approximately zero.
  - The reducing environment created at surfaces is demonstrated by low ECP measurements.
  - Evaluation of inspection data provides confidence in mitigation effectiveness

In Progress

- Work is being performed to identify criteria when a plant component surface is covered "well enough" with Pt particles to behave fully catalytic and therefore to reach IGSCC mitigation.
- Research performed to date shows relationships between Pt mass loading and inter-particle distance, and ECP vs Pt loading or mean inter-particle distance.
- Studies on laboratory-prepared specimens and harvested plant artifacts are in-progress to validate Pt particle Field Emission – Scanning Electron Microscopy (FE-SEM) measurement techniques and relate plant results to laboratory results.
- Modeling of the platinum deposition is on-going with benchmarking to plant results.
- Particle size, distribution, spacing, density, and mass loading are being correlated to ECP readings. In-line ECP measurements provide confirmatory data to indicate sufficient Pt is present on the monitored surfaces.



Plant data



Lab data

Inspection Data Collection and Inspection and Evaluation Guidance Optimization

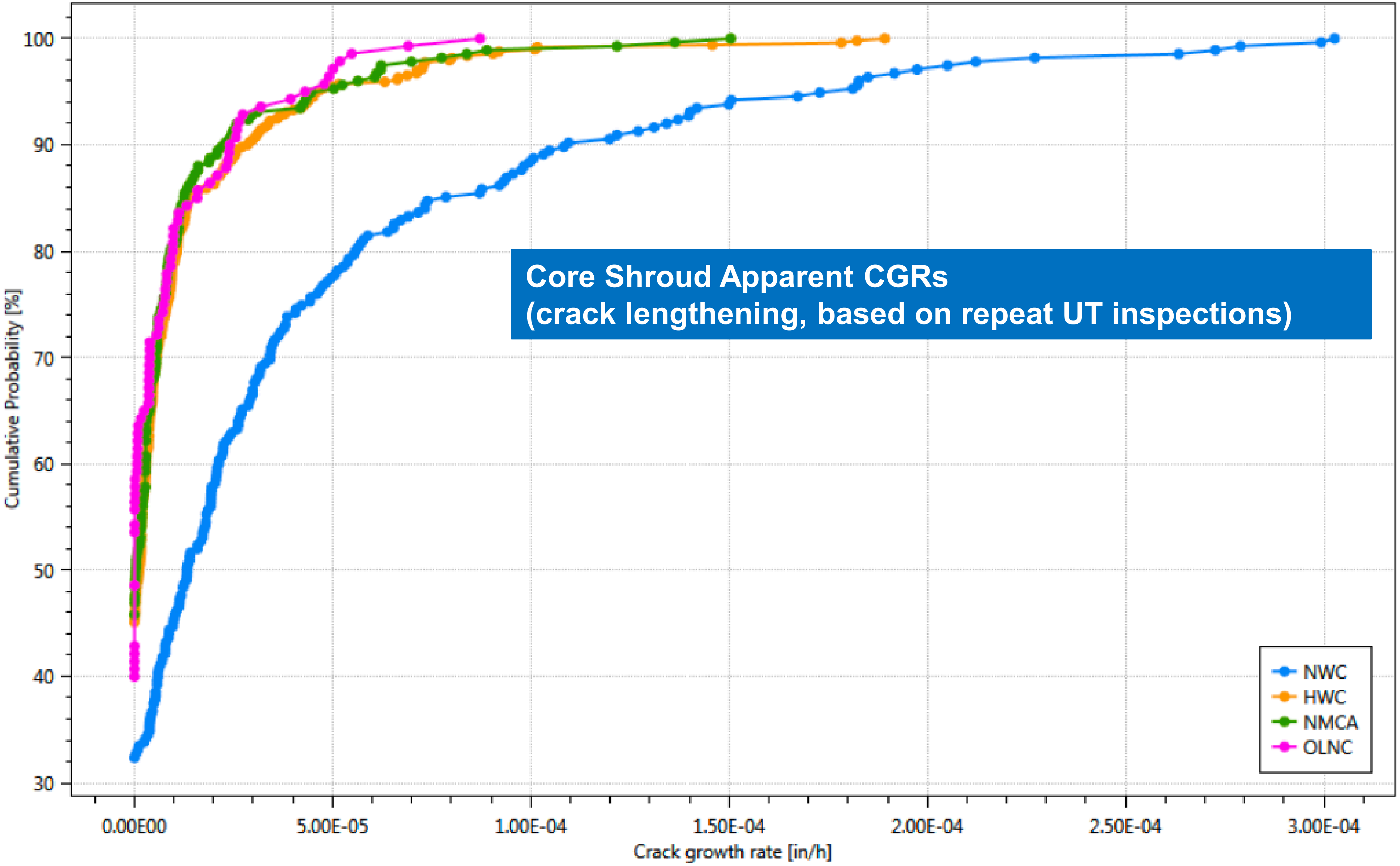
Inspection Data Collection

- Historically, the BWRVIP has expended significant resources to collect information on degradation identified in BWR RPV and reactor internals
- Since 2018, the BWRVIP has been maintaining and expanding an inspection records database that includes
  - Detailed inspection data (technique, coverage, relevant BWRVIP demonstration for UT examinations)
  - Detailed flaw characterization data (flaw lengths, depths, locations)
  - All U.S. BWRs and some international BWRs contribute detailed inspection data
- Where determined to be of significant value, detailed inspection data from earlier inspections have been added to this database
- Environmental data are also included
  - Water chemistry technologies in use and water chemistry excursion details
  - Fluence data (summary data for some plants, detailed fluence maps for a limited number of plants)

Inspection Data Analysis and Application

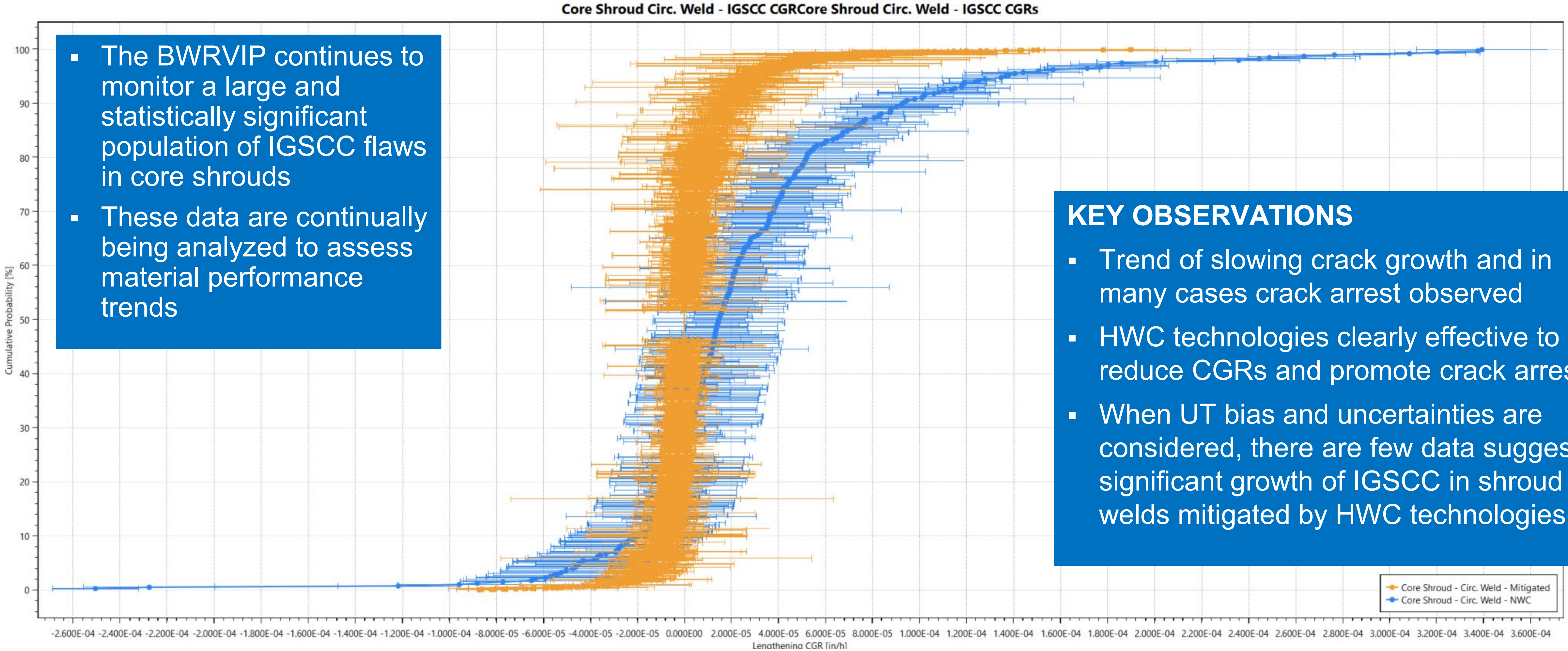
- Database includes a comprehensive suite of statistical tools for comparing and characterizing datasets
- As this database matures, the BWRVIP is now considering how to apply the resulting data correlations and trends to refine aging management guidance
- Potential applications include
  - Improved quantification of SCC mitigation by HWC technologies
  - Refinement of periodic inspection program requirements based on an improved understanding of SCC susceptibility derived from field inspection data
  - Assessment of margins associated with experimentally derived SCC CGR correlations derived from comparison of experimental CGR correlations with apparent CGRs derived from field data
  - Demonstration that once crack arrest occurs, a return to active flaw growth is highly unlikely

Inspection Data Analysis Example: Shroud CGRs (1 of 2)



Source: BWRVIP-174, Rev. 2

Inspection Data Analysis Example: Shroud CGRs (2 of 2)



- The BWRVIP continues to monitor a large and statistically significant population of IGSCC flaws in core shrouds
- These data are continually being analyzed to assess material performance trends

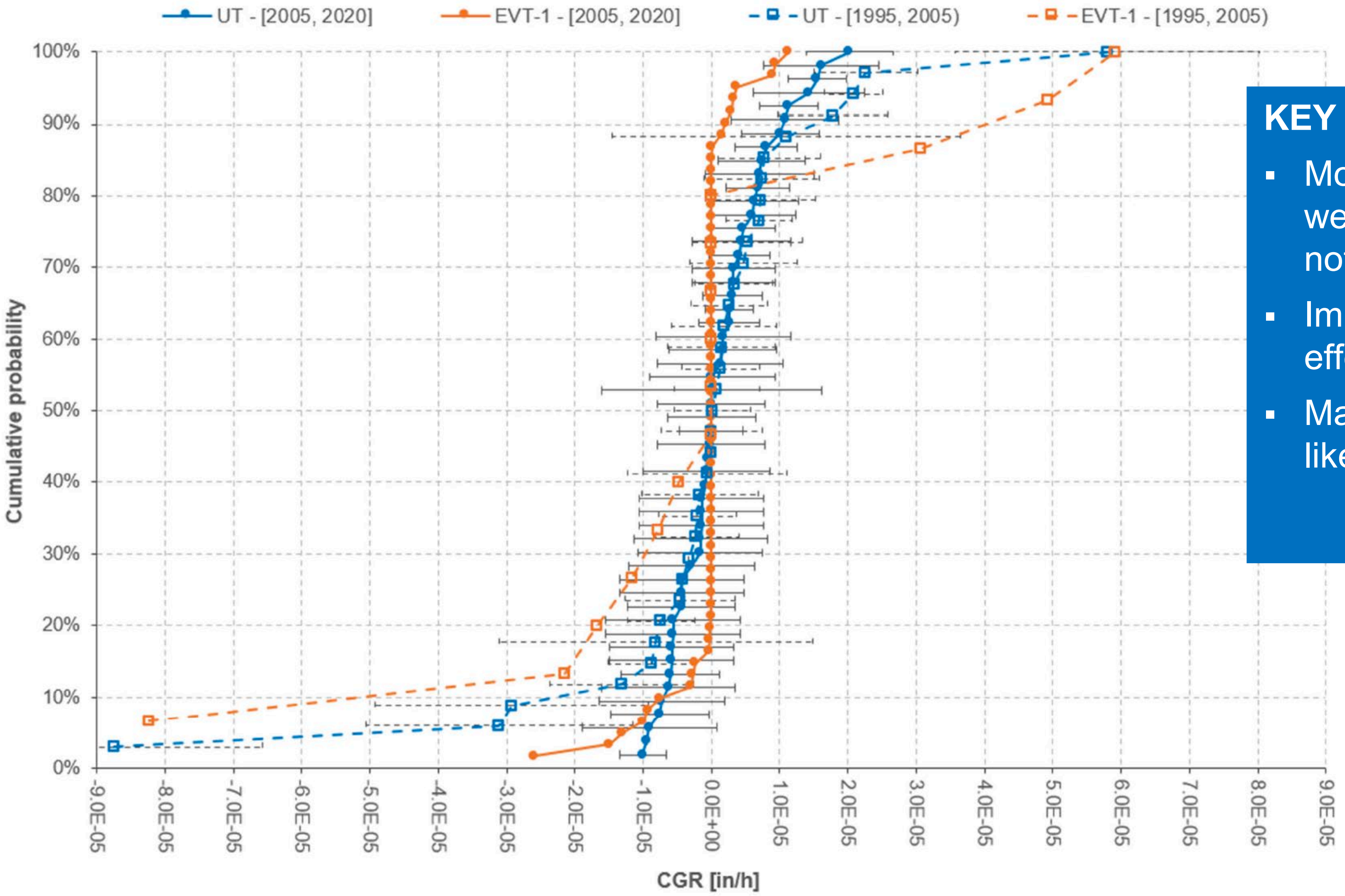
KEY OBSERVATIONS

- Trend of slowing crack growth and in many cases crack arrest observed
- HWC technologies clearly effective to reduce CGRs and promote crack arrest
- When UT bias and uncertainties are considered, there are few data suggesting significant growth of IGSCC in shroud welds mitigated by HWC technologies

Data source	Set	Name	Population	Standard deviation	Mean	Median	Mode	25th percentile	50th percentile	75th percentile
CGR	Lengthening CGR	Core Shroud - Circ. Weld - NWC	404	6.217E-05	2.835E-05	1.468E-05	0.000E00	0.000E00	1.468E-05	4.388E-05
CGR	Lengthening CGR	Core Shroud - Circ. Weld - Mitigated	4083	1.708E-05	3.077E-06	0.000E00	0.000E00	-2.977E-06	0.000E00	5.076E-06

Source: unpublished data – BWRVIP Inspection Database

Inspection Data Analysis Example: Core Spray Piping Weld CGRs



KEY OBSERVATIONS

- Most IGSCC flaws in core spray piping welds appear “dormant” and have likely not grown for many years
- Improving NDE capabilities have been effective in reducing inspection uncertainty
- Many of the high CGRs from initial studies likely were the result of NDE factors

Source: BWRVIP-339

Summary

- The BWRVIP is a living program focusing on aging management and safe operation
- BWRVIP continues to monitor and evaluate material/component degradation across the BWR fleet, both domestically and internationally
- Information gathered is being used to guide inspections and flaw evaluation methods and/or validate methods to mitigate IGSCC


Together…Shaping the Future of Energy®

ACRS/EPRI Materials Reliability Issues Update Meeting

Materials Reliability Program Overview (PWR materials-related items)

Bob McGill
EPRI, MRP Program Manager

Kyle Amberge
EPRI, MRP Technical Executive

ACRS Fuels, Materials, and Structures SC Meeting
March 22, 2023

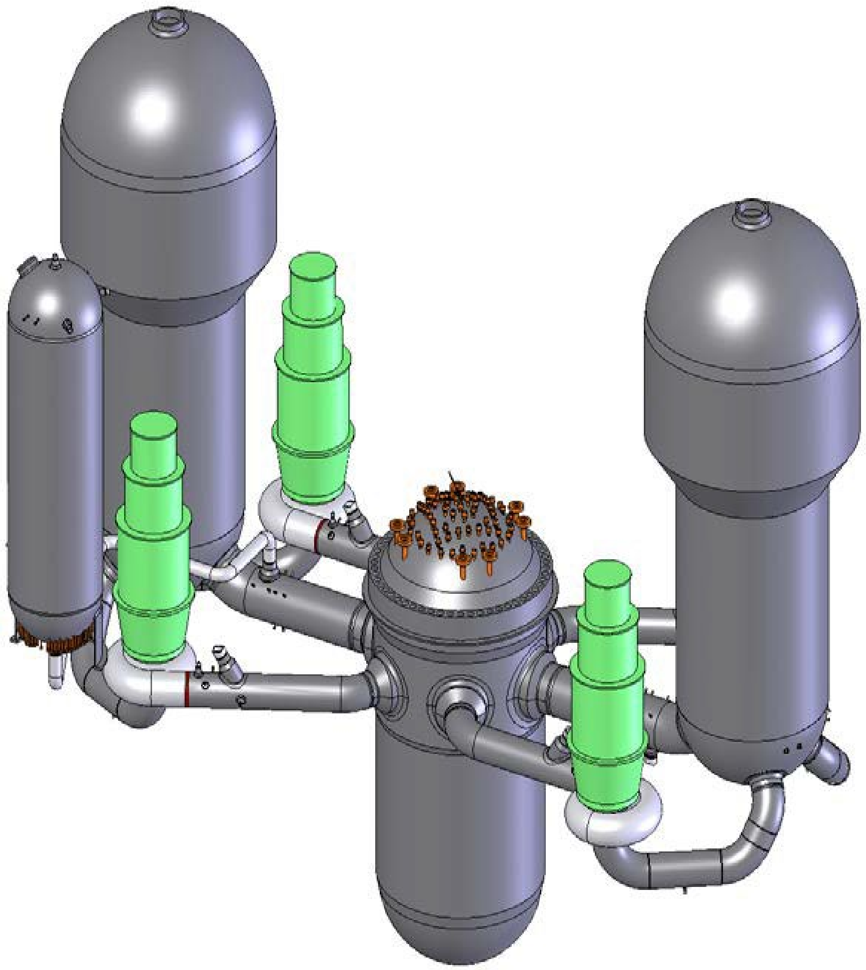
Presentation Agenda

- EPRI-Materials Reliability Program Overview
- Overview of Major Projects and Industry Engagement
  - NRC safety evaluation of MRP-227, Rev. 2
  - MRP/PWROG core barrel focus group
  - MRP/PWROG stainless steel SCC focus group
  - Irradiated stainless steel fracture toughness data assessment
  - Environmentally-assisted fatigue component testing

EPRI-MRP Overview

MRP Overview

- PWR specific materials issues in the late 1990s led to the formation of the EPRI Materials Reliability Program (MRP) within the Nuclear Sector
- EPRI's MRP supports efforts to assess and implement countermeasures for degradation mechanisms impacting materials in PWR primary systems
- Program research provides utilities and regulatory agencies with the information necessary to make technically sound and cost-effective decisions for managing materials degradation



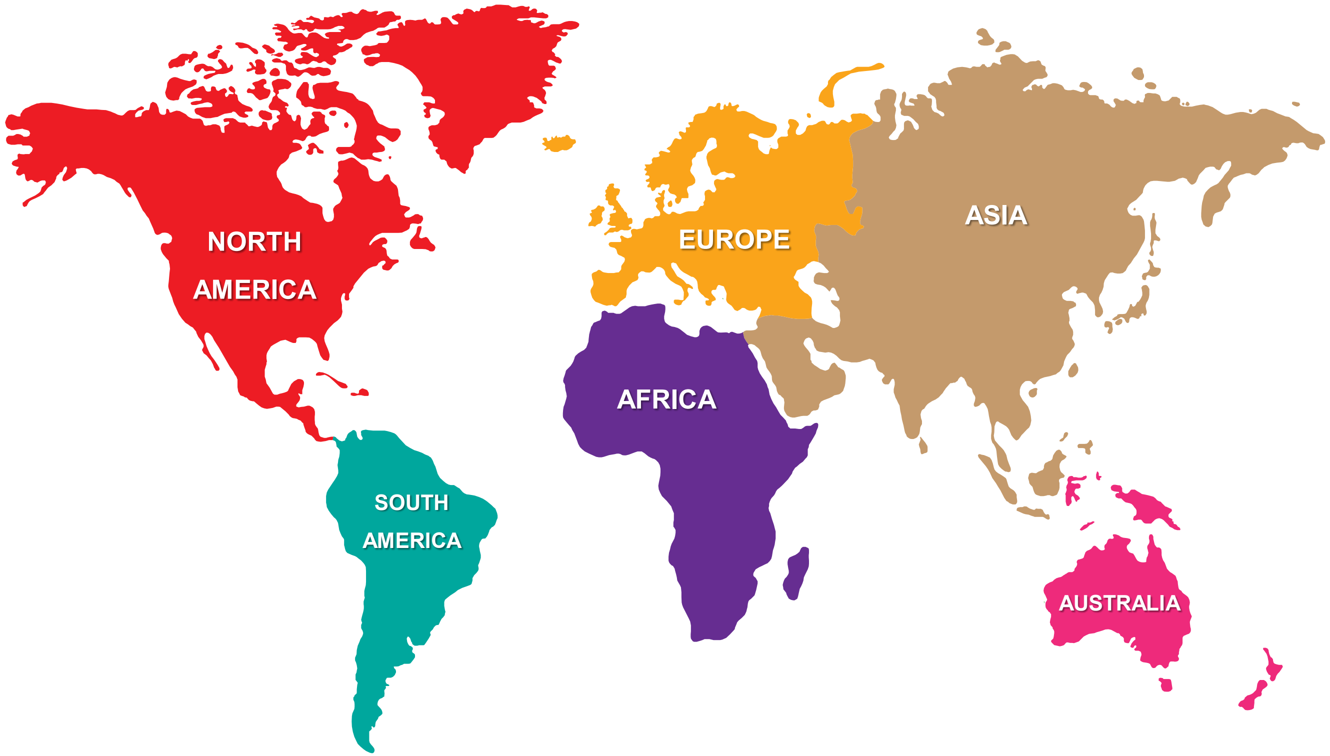
<u>MRP Scope</u>: Reactor pressure vessel and internals, reactor coolant system piping, and pressurizer

EPRI

MRP Member Utilities for 2023

North America

- Ameren Services Company
- American Electric Power Service Corporation
- Constellation Energy Corp.
- Dominion Energy, Inc.
- Duke Energy Corp.
- Energy Harbor Corp.
- Entergy Services, LLC
- Evergy Services (Wolf Creek)
- NextEra Energy, Inc.
- Pacific Gas & Electric Co.
- Pinnacle West Capital Corp.
- PSEG
- Southern Nuclear
- STP Nuclear Operating Co.
- Tennessee Valley Authority
- Vistra Energy/Comanche Peak
- Xcel Energy Services, Inc.



Europe

- Axpo (Switzerland)
- EDF Energy (UK)
- Foro-CEN (Spain)
- Rolls-Royce SMR (UK)
- Rolls-Royce Submarines (UK)
- Vattenfall (Sweden)

Asia

- China National Nuclear Power
- Emirates Nuclear Energy Corp.
- Japan Atomic Power Company
- Kansai Electric Power Co.
- Korea Hydro & Nuclear Power
- Kyushu Electric Power
- Shandong Nuclear Power Co.

South America

- Eletrobras Termonuclear S.A.

MRP Team for 2023

THE MRP TEAM

Bob McGill, Program Manager (rmcgill@epri.com)

Kyle Amberge, RPV Internals, OE (kamberge@epri.com)

Tom Damiani, Fatigue Management (tdamiani@epri.com)

Amy Freed, Project Management (afreed@epri.com)

Nate Glunt, RCS Piping (nglunt@epri.com)

Craig Harrington, xLPR, Data Management (charrington@epri.com)

Elliot Long, RPV Integrity (elong@epri.com)

Morgan Saucier, Program Communications (msaucier@epri.com)

DJ Shim, Fracture Mechanics (dshim@epri.com)

- Three former utility engineers
- Four former NSSS engineers
- Six active ASME Code members
  - Section III and Section XI
- Advanced engineering degrees
  - Four Masters of Science
  - Three Doctors of Philosophy

Currently recruiting for a nickel-based alloy lead.

MRP Organization and Advisory Structure for 2023

Research Integration Committee

Provides TAC oversight and makes project funding decisions

Chair: Pål Efsing, Vattenfall

Vice Chair: Tyler Whaley, Ameren

MRP RIC PM: Bob McGill

Technical Advisory Committees

Internals & Integrity

Chair - Corey Thomas, Southern

Vice Chair - Jasmyn Bone, Entergy

MRP TAC PM - Elliot Long

All technical issues related to reactor pressure vessel internals assessment, stainless steel alloys, and reactor pressure vessel integrity

Pressure Boundary

Chair - Lora Drenth, Constellation

Vice Chair - OPEN

Acting MRP TAC PM – Bob McGill

All technical issues related to nickel-based alloys and thermal, vibration, and environmentally-assisted fatigue

Inspection

Chair - Dale Brown, Southern

Vice Chair - Todd Davis, Constellation

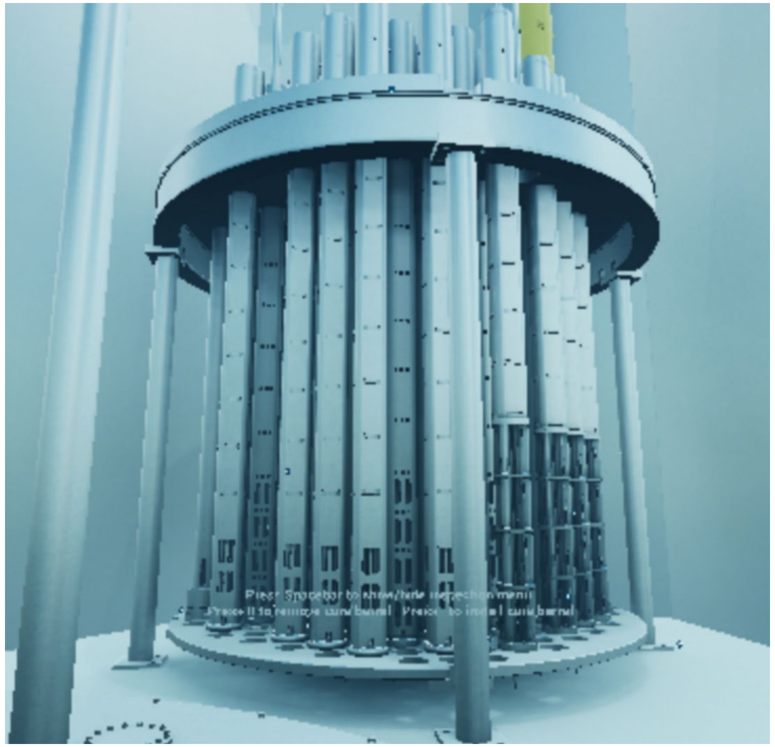
MRP TAC PM - Bob Grizzi

All technical issues related to inspection technique, available equipment, and reliability of results

Overview of Major Projects and Industry Engagement

NRC Safety Evaluation of MRP PWR Internals Inspection and Evaluation Guidelines, MRP-227, Rev. 2 (1/2)

- MRP-227, Rev. 2 provides PWR inspection and evaluation guidance for RPV internals operating beyond their original license and is a publicly available document
- Consistent with previous MRP-227 revisions, an NRC Safety Evaluation has been requested by the industry to help streamline SLR application approvals
- MRP is working with Westinghouse and Framatome in responding to NRC's requests for additional information (RAIs) – responses should be provided by 4/1



EPRI

NRC Safety Evaluation of MRP PWR Internals Inspection and Evaluation Guidelines, MRP-227, Rev. 2 (2/2)

- Recent operating experience (OE) with discovered PWR core barrel cracking may require updates to the component categorizations given in MRP-227, Rev. 2 – these updates would be reflected in the NRC approved revision, MRP-227, Rev. 2-A
- The specific updates are currently being developed by an MRP/PWROG Focus Group (see next slide)
- As the MRP-227 guidance is a “living program,” MRP and the industry team will continue to engage with NRC staff to address OE and any guidance updates on a timely basis

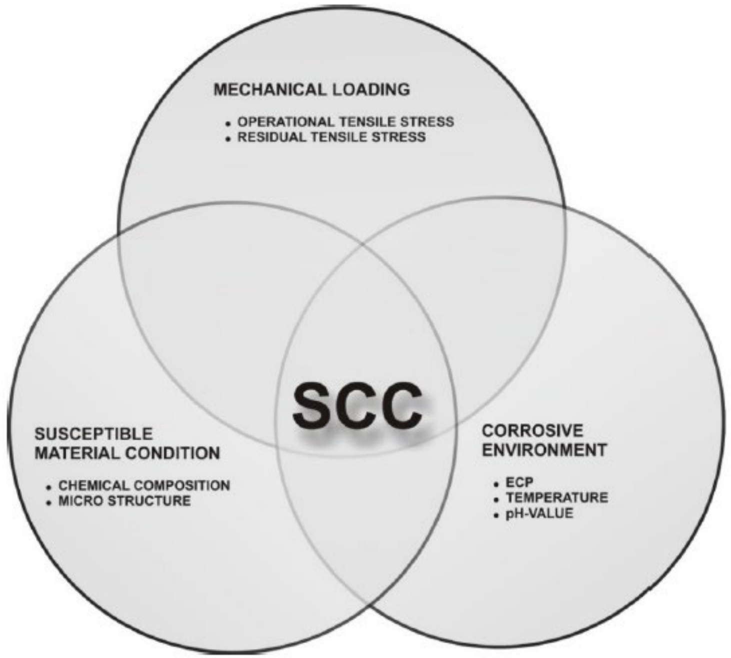
MRP/PWROG Core Barrel Focus Group

- In response to the recently observed PWR core barrel cracking, the MRP/PWROG have restarted a Focus Group to assess possible guidance changes consistent with the NEI 03-08 Materials Initiative process
- The first hybrid meeting was held in Charlotte on 2/9
- Several actions were identified ranging from analysis to testing to repair options

Focus Group will remain active through 2023 (longer if needed)

MRP/PWROG Stainless Steel SCC Focus Group (1/2)

- MRP continues to support the Stainless Steel SCC Focus Group with the PWROG in response to the EDF OE
- Two reports are being prepared for utility members:
  - Safety Assessment Report – out for utility member comment
  - Applicability Assessment Report – draft expected later in 2023



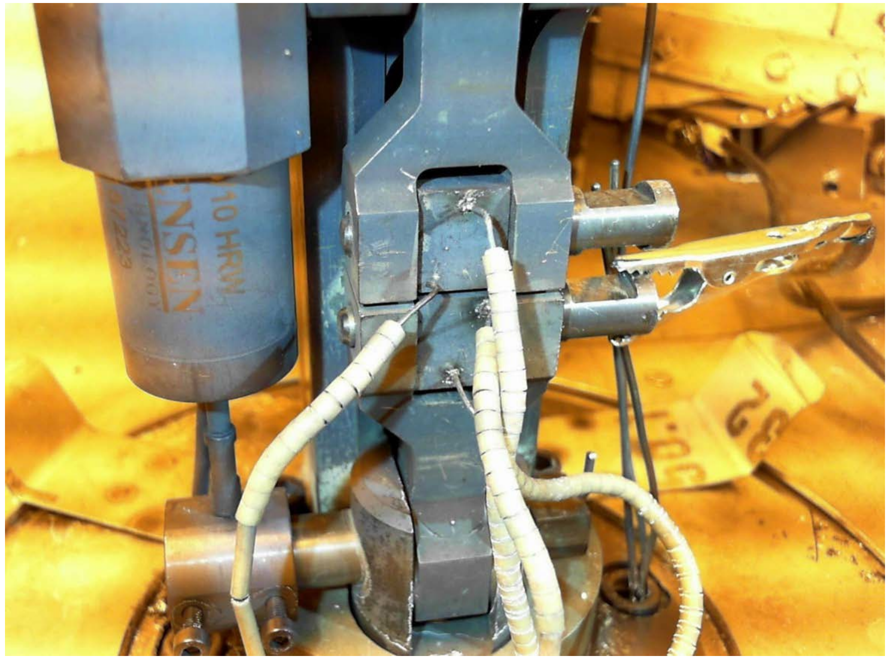
Focus Group will remain active through 2023 (longer if needed)

MRP/PWROG Stainless Steel SCC Focus Group (2/2)

- In 2022, MRP published 2 related documents (both made public):
  - MRP Letter Report, “Current Knowledge State of Stainless Steel Stress Corrosion Cracking in Pressurized Water Reactor Environments”
  - MRP Technical Report, “Stress Corrosion Crack Growth Rates in Stainless Steels in PWR Environments (MRP-458)”
- In 2023, MRP will update the technical report “SCC of Stainless Steel Components in Primary Water Circuit Environments of PWRs” (MRP-236) to reflect EDF OE

Irradiated SS Fracture Toughness Data Assessment (1/2)

- In March 2021, EPRI issued Part 21 report BWRVIP 2021-030 to inform NRC of recent lower fracture toughness test results in irradiated stainless steel welds and HAZs
- Implications to BWR plants are likely minimal, but there could be more significant implications to PWR plants due to their higher fluences



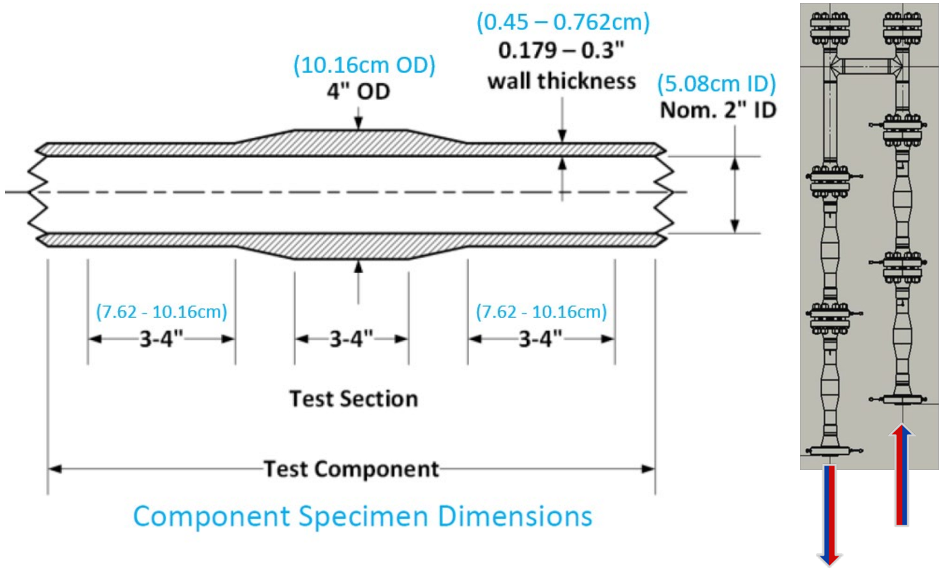
Irradiated SS Fracture Toughness Data Assessment (2/2)

- EPRI report MRP-210 documents that reduction in fracture toughness occurs primarily between 1 and 10 dpa
- Results show that the fracture toughness reaches a minimum 'saturation' level after approximately 10 dpa
- EPRI has been working with Westinghouse to reevaluate the raw test data from recent tests and identify any adjustments in the dataset for PWRs
  - Applicable fluence ranges and lower bound values may be different than what has been used/proposed by the BWRVIP and will likely be different for welds and HAZs
  - EPRI will update MRP-210 technical report upon completion of efforts

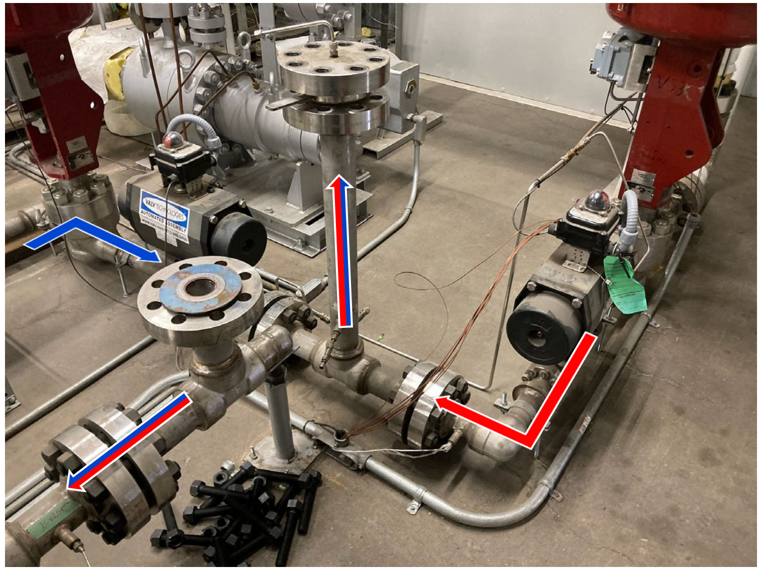
EAF Component Test

- Better quantify margins in current fatigue assessment methods
- Provide benchmark data for new fatigue assessment methods
- Allow comparison of different methods: international round robin predictions of EAF degradation for the component

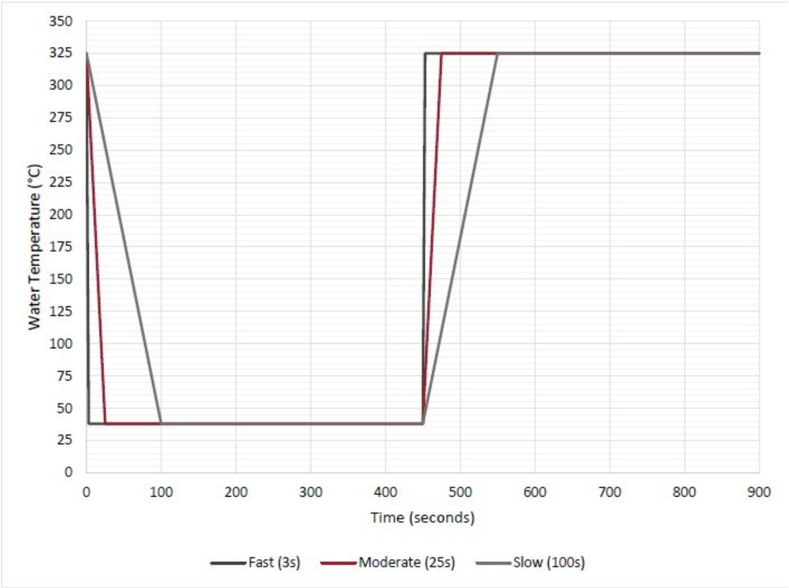
Test Specimen



Test Loop



Transients



EAF Component Test Process

Phase 1: FEA Modelling and Design

- Define component parameters
- Define transient parameters
- Component FEA model outputs
- Predict fatigue behavior

Phase 2: Commissioning (YOU ARE HERE)

- Thermal and strain FEM benchmarking
- NDE calibration
- FEA alignment
- NDE crack siding calibration
- Revise fatigue predictions

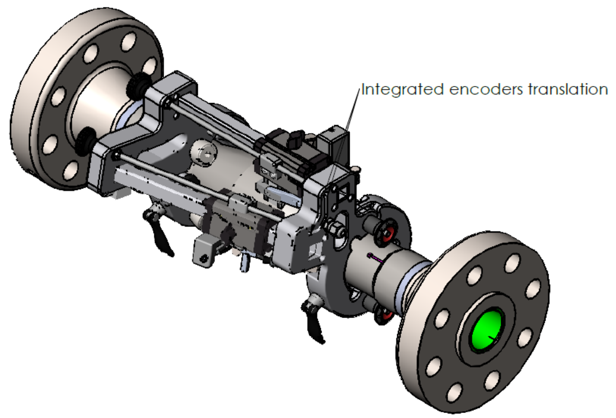
Phase 3: Testing

- Initiate fatigue cracks
- ET for crack detection
- Propagate fatigue cracks
- UT for crack growth monitoring
- Post-test examinations

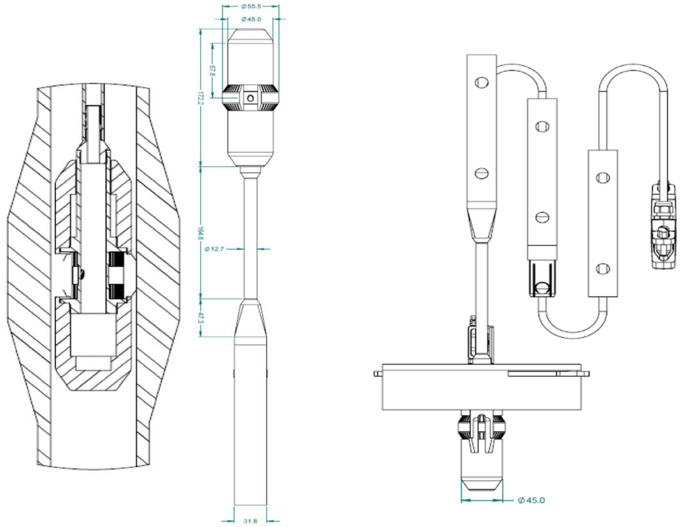
Phase 4: Integration into FEA Models

- Calculate CUF (crack initiation)
- Calculate through-wall crack growth

OD – Crack Propagation



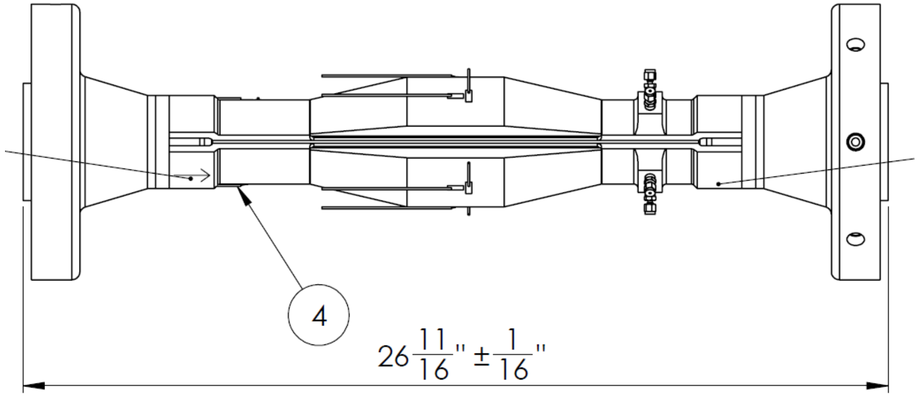
ID – Crack Initiation



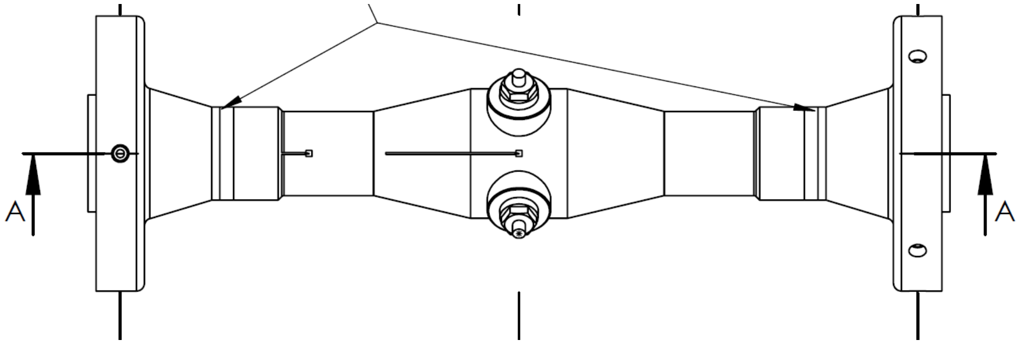
2023 EAF Component Test Activities

Begin loop shakedown testing	3/2023
Complete fabrication and instrument placement of thermal/strain benchmarking and NDE qualification specimens	5/2023
HOLD POINT: EPRI EAF Team approval to begin commissioning test – stress and thermal benchmarking specimens.	6/2023
Complete stress and thermal benchmarking test	9/2023
Complete NDE qualification test and assess results	10/2023

Strain Benchmarking Specimen



Thermal Benchmarking Specimen



Discussion


Together…Shaping the Future of Energy®

Steam Generator Management Program (SGMP)

Helen Cothron
EPRI, Program Manager

ACRS Fuels, Materials, and Structures SC Meeting
March 22, 2023

SGMP Global Membership

100% of U.S. Pressurized Water Reactors and 1 US Laboratory

15 International Members

Axpo Power AG

CANDU Owners Group

CRIEPI (Japanese Utilities)

China National Nuclear Power

EDF Energy Nuclear Generation,

Ltd. Electrabel NV (ENGIE)

Eletronuclear

Emirates Nuclear Energy Corp.

Foro de la Industria Nuclear

Korea Hydro & Nuclear Power

Nucleoelectrica Argentina S.A.

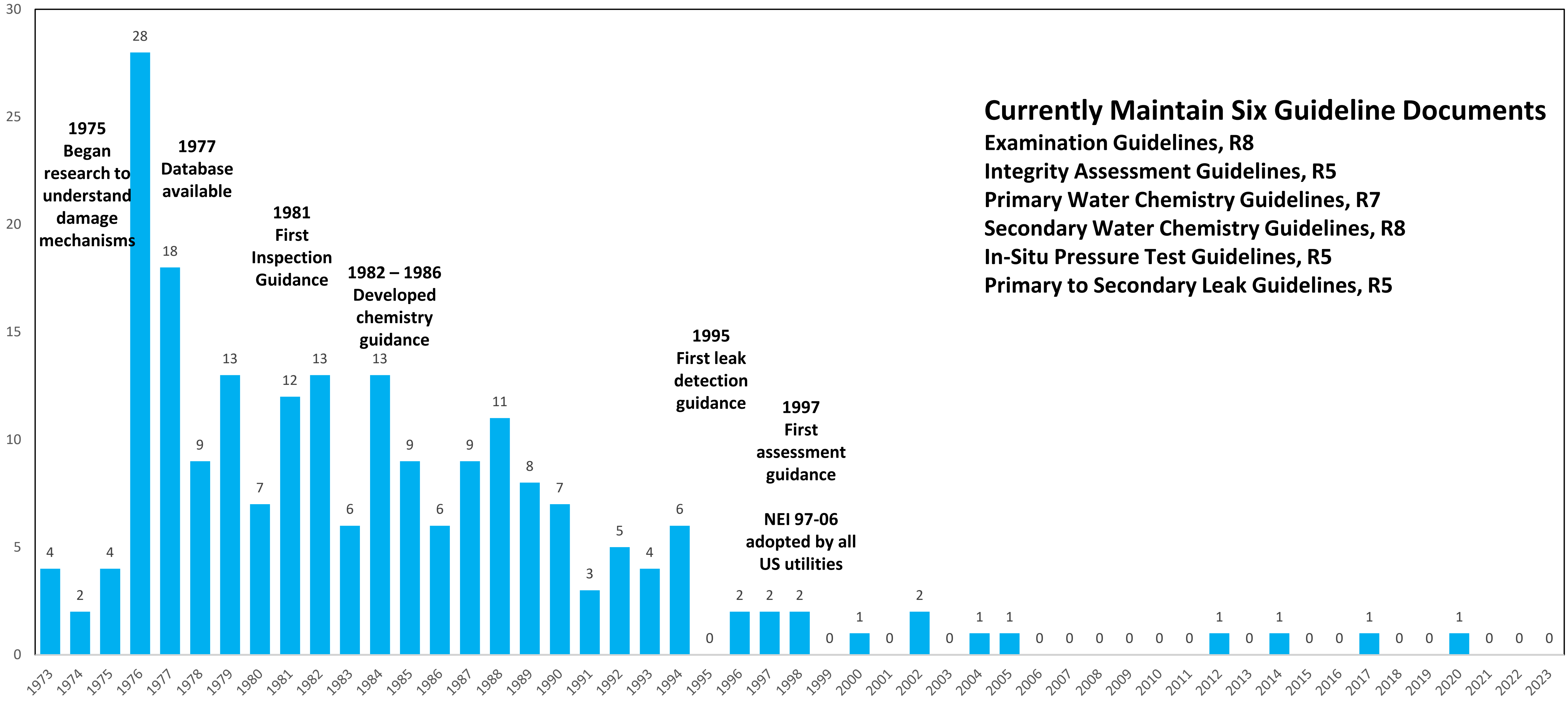
Rolls-Royce SMR Limited

State Nuclear Power Tech Corp

Taiwan Power Company

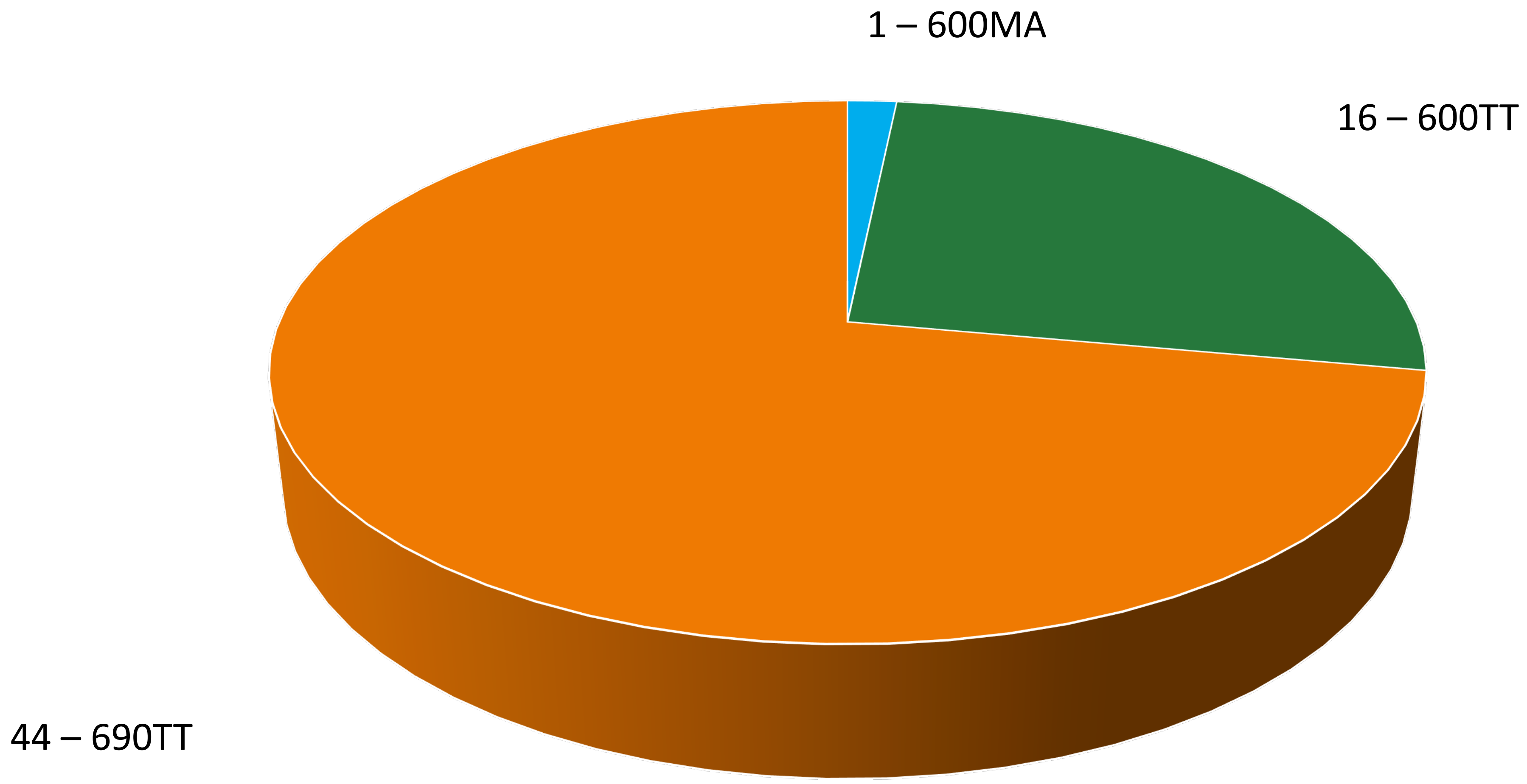
Vattenfall AB

Steam Generator Management Program Success Story



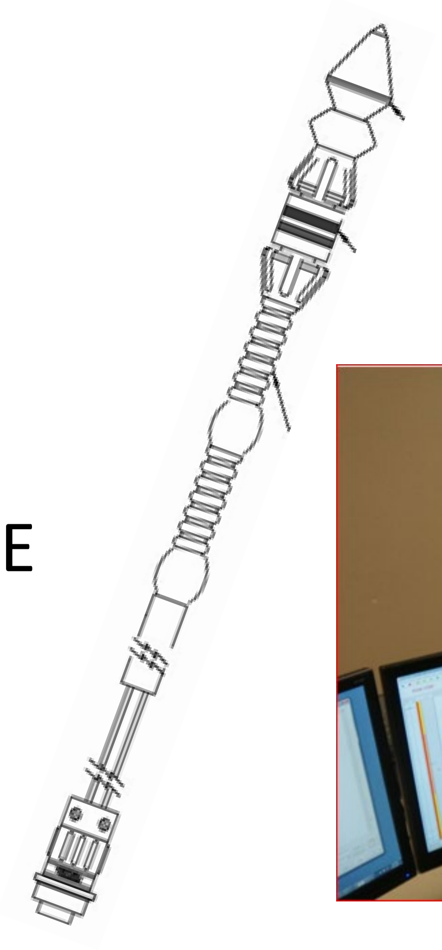
Tube Leak Outages by Year (US Data Only)

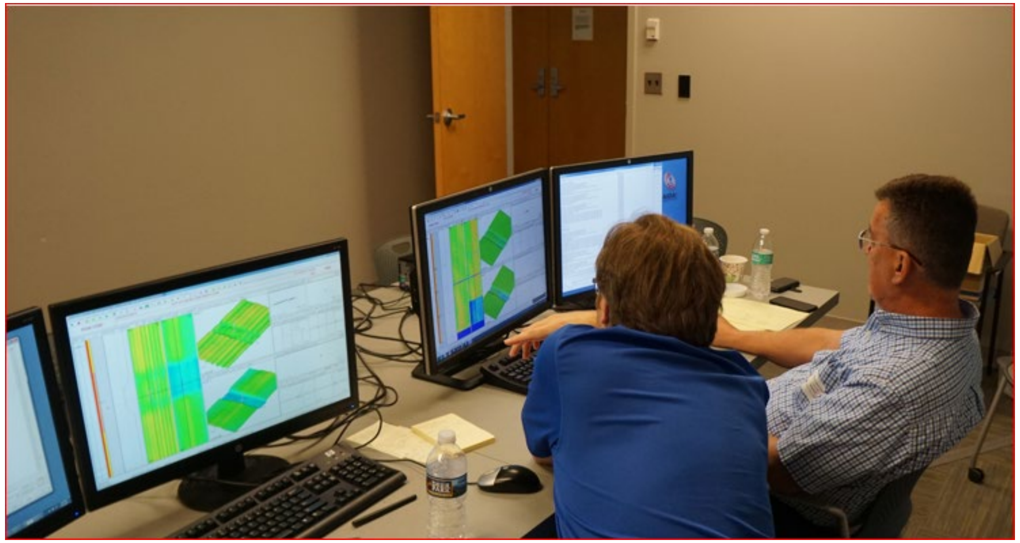
US Steam Generator Tube Material



Qualification of NDE Techniques/Personnel/Software

- Eddy current technique
  - 10 CFR 50 Appendix B qualification program
  - Ensures consistent, accurate inspections
  - Documents performance of NDE systems
- Extensive database and software for testing analysts and automated systems
  - Generic qualification
  - Site-specific qualification





Steam Generator Degradation Database (SGDD)

SGDD by the numbers:

- >1,000 steam generators
- >90 models
- >4,500 inspections worldwide
- >1.8 million tubes
- >75 chemical cleanings

Outage Tables

- Outage information
- Leakage experience
- NDE scope and degradation mechanisms
- Tube repair status
- In-situ pressure testing
- Pulled tube data
- Sludge removal
- Loose parts info
- Secondary side status

Plant Data

- Utility experience
- Plant information
- Steam generator design
- Replacement steam generator details
- Plant operations
- Leakage monitoring

EPRI Tables

- SGDD users
- NDE results
- Primary chemistry data – cycle and monthly
- Secondary chemistry data – cycle and monthly
- Auxiliary systems
- SGMP chemistry metric

Strategic Planning

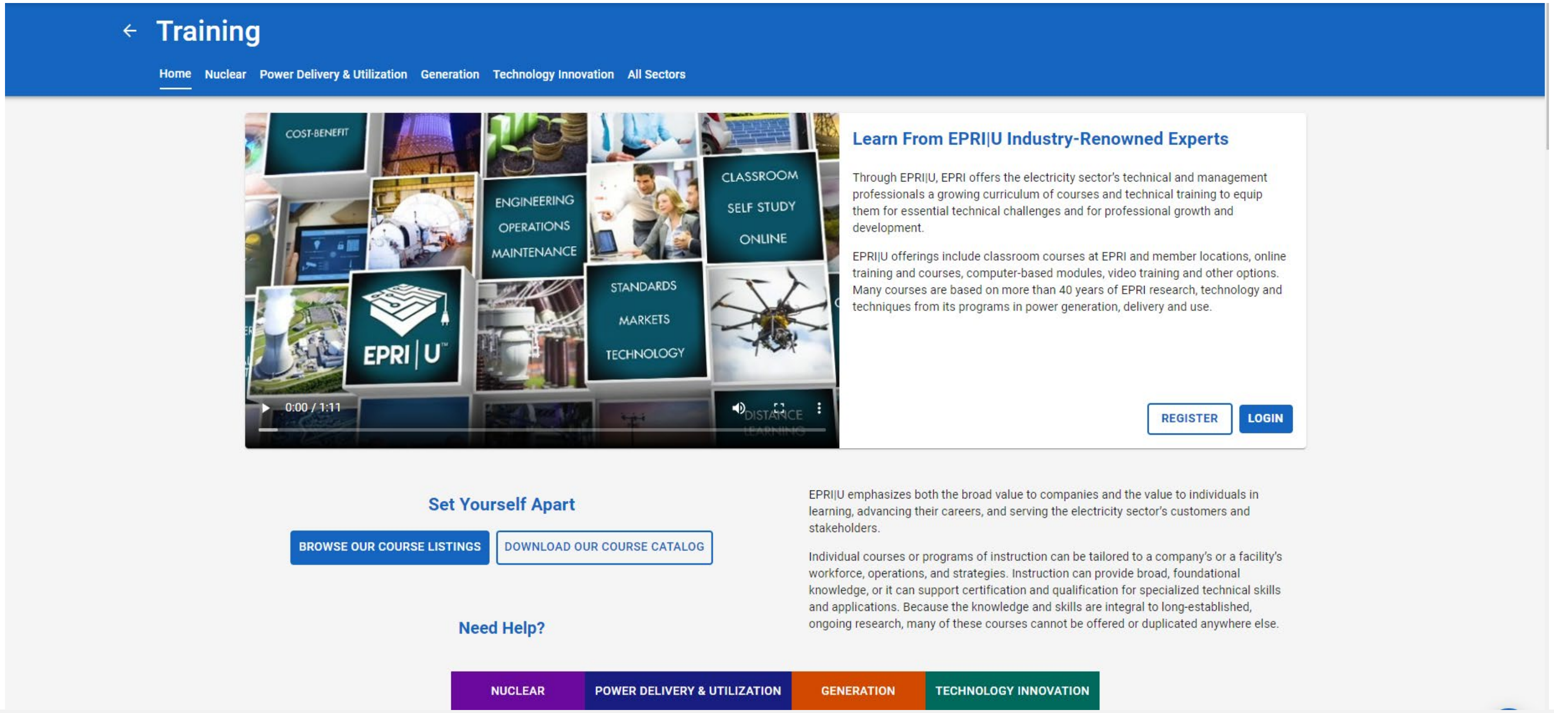
Plan for steam generator replacement and chemical cleanings

Tactical Planning

Benchmark what to inspect and when; optimize inspections (amount/frequency)

Training

- SGMP has 19 training modules in EPRIU
- Additional training will be available soon
  - Specifics on tube integrity analysis – 2023
  - Virtual reality training for steam generator components - 2024



SGMP Provides Tools for Performing Needed Assessments

- Software for Determining High Stress Tube Population (Alloy 600TT)
- Performance and Reliability Database
- Foreign Object Wear Predication Software
- Operational Assessment Software Tools
- Eddy Current Simulation Software
- Triton Thermal/Hydraulics Code

Secondary Side Maintenance Has Become a High Priority

- SGMP research is trying to address the following concerns
  - Trigger points for planning chemical cleanings
  - How to measure broached hole tube support plate blockage
  - Appropriate sludge lance and foreign object search and retrieval frequencies
  - Thermal performance trending

Research Funded by Focus Areas

Chemistry and Fouling

- Hydrazine Alternative Development
- Effect of Dispersant on:
  - Two Phase FAC
  - Thermal Performance
  - Sludge Pile Softening
- Film Forming Products
- Steam Generator Layup Sourcebook
- Broached Hole Blockage Estimation Methods
- Risk Assessment for PWRs to Support Risk-Informed Chemistry
- Test Facility to Investigate Heat Transfer Characteristics of Tube Deposits
- Update Operating Experience for Secondary Side Component Maintenance Activities

Research Funded by Focus Areas

Wear

- Model to Predict Wear in Steam Generators Due to Foreign Objects
- Material Characteristics of Tube Scale that Could Cause Wear on Tubes
- Probabilistic model to perform wear degradation tube degradation calculations
- Update to operating experience and research results for foreign objects

Research Funded by Focus Areas

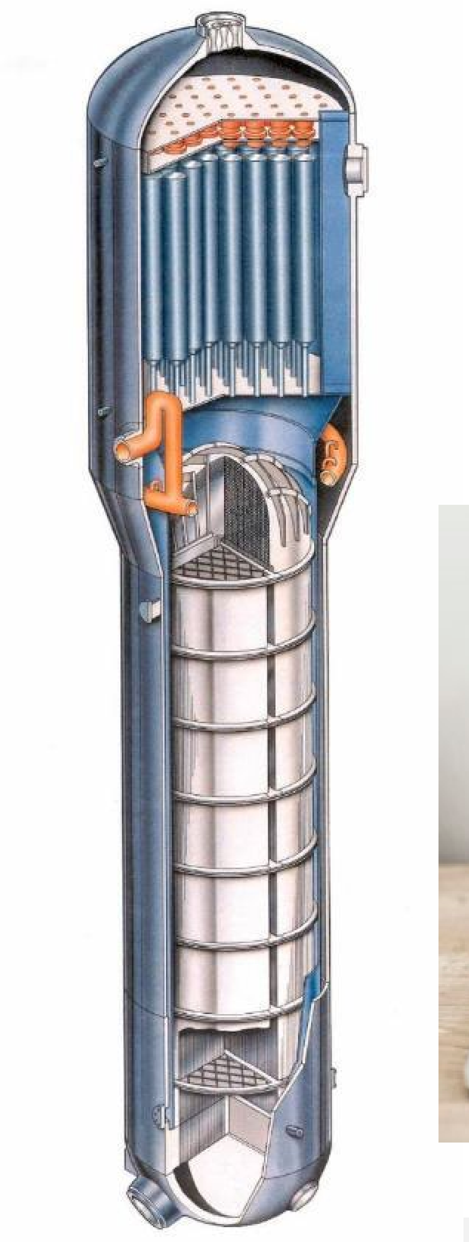
Inspection

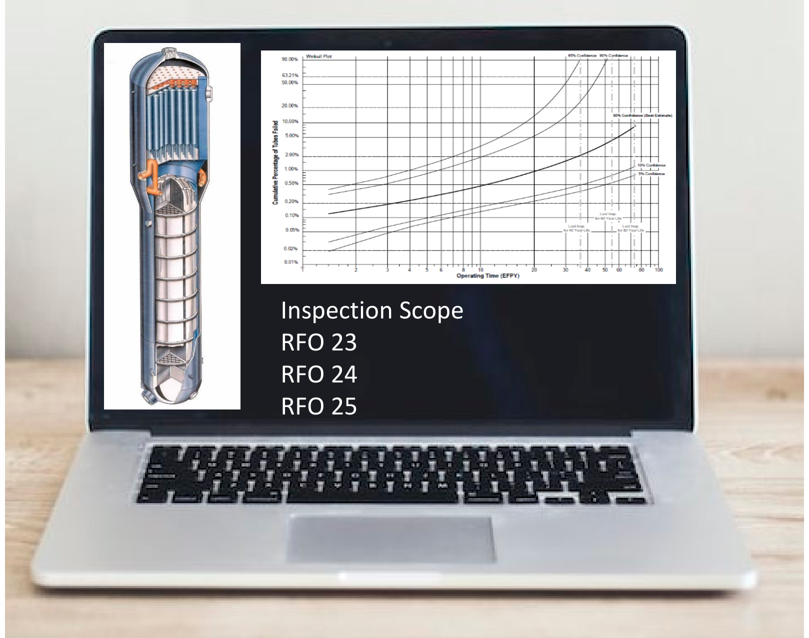
- Fabrication and Destructive Analysis of Samples for Qualification Work
- Assessment of Tube Deposit Effect on Eddy Current Signal
- Steam Generator Eddy Current Simulation Software
- Depth Sizing from Secondary Side of Tube
- Eddy Current Noise Monitoring
- POD Modeling Updates

Research Funded by Focus Areas

Nickel-based Alloys	• Qualification of Inhibitors for Lead SCC • Research Studies on Retired Steam Generators–SHERLOCK • SG Generic Predication Lifetime Analysis • Tube Removal Sourcebook Update
Flow Phenomena	• Triton Version 1.1 • New Database on Thermal Performance

Looking Into New Technology - Digital Twin





- SGMP is investigating development of digital twin technology for steam generators
- First step address questions such as:
  - What plant data could be used to populate a digital twin database
  - How can we safely store this data
  - How can real time plant data be used for trending performance
  - Can inspection data be input to provide better predictions for the future
  - Can the data that we already obtain from utilities be used to populate the digital twin database

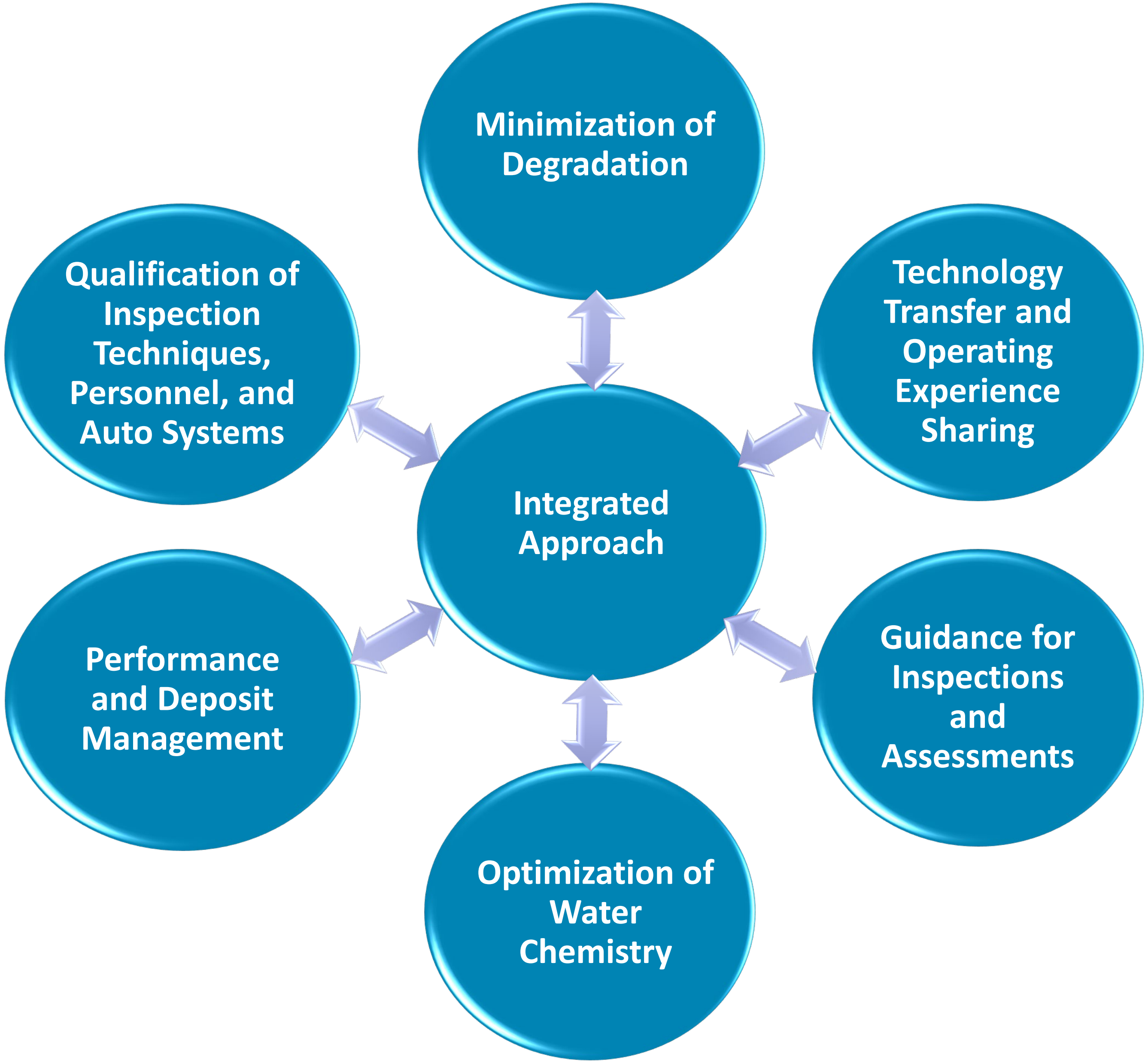
SGMP Interactions with the US NRC Technical Staff

- SGMP meets twice per year with the Corrosion and Steam Generator Branch
- SGMP holds workshops from time to time to keep the technical staff and region inspectors up to date on latest technology
  - An auto analysis workshop will be held June 2023
    - Expect 20 participants from the NRC

Time	Topic	Speaker
1:00 pm	Welcome and Introductions	All Participants
1:10 pm	Opening Remarks	NRC and Industry
1:15 pm	Industry Presentation: 1. Recently Published Reports 2. Status of Industry Guidelines 3. Interim Guidance 4. Nuclear Energy Institute 03-08 Deviations 5. Recent Operating Experience – None to Report 6. Inspection Plans from EPRI TSTF-577 Implementation Letter (ML22200A268) 7. SGMP ETSS Status 8. Eddy Current Simulation Software Status	Industry H. Cothron J. Mayo S. Brown R. Guill J. Benson
2:45 pm	Break	All Participants
3:00 pm	1. Standard Technical Specification Section 5.6.7.c.2 – Reporting Tube Wear at Support Structures Less than 20 Percent Through-wall 2. NUREG-2191 Update Schedule	NRC
3:20 pm	Address Public Questions/Comments	NRC
3:30 pm	Adjourn	

Summary

- World-wide forum for operating experience
  - 100% of US utilities
  - 1 US Laboratory
  - 15 International utilities
- Guidance for developing and maintaining a strong steam generator program through six Guideline Documents
- All US utilities and some international utilities have adopted the SGMP guidelines into plant procedures
- Utilities can use the SGMP guidance for managing their steam generators for extended periods of operation



Together…Shaping the Future of Energy®

International Materials Research (IMR)

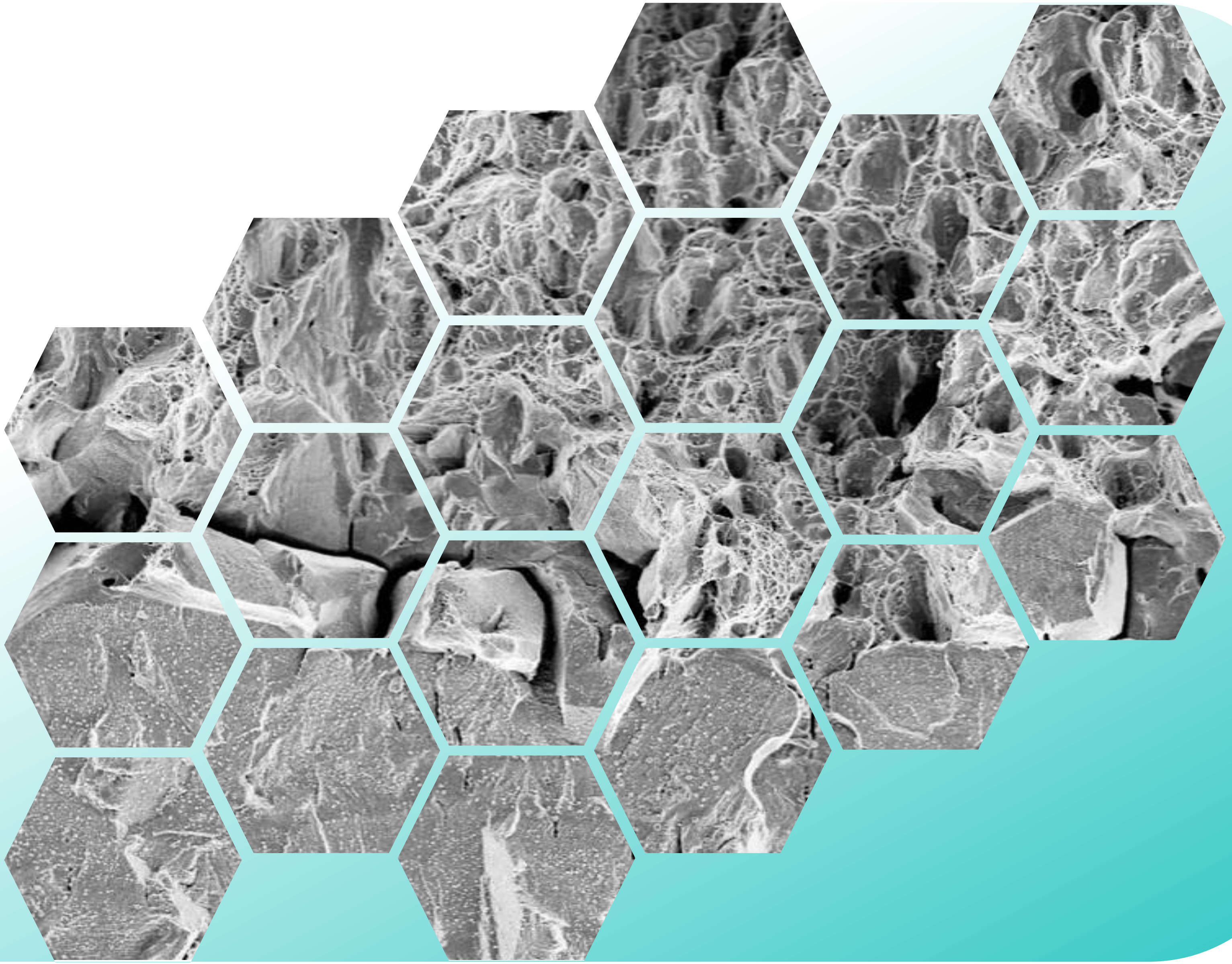
Program Overview

Jean M. Smith, PhD PE
EPRI, Program Manager

ACRS Fuels, Materials, and Structures SC Meeting
March 22, 2023

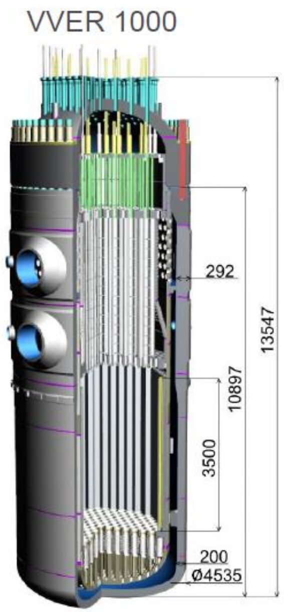
Agenda

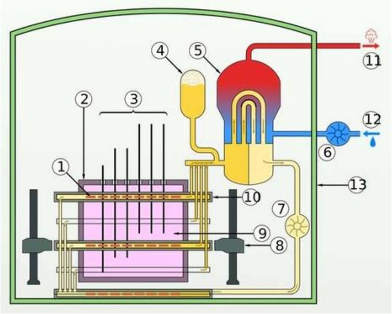
- International Materials Research
  - Program Objectives
  - Members
  - Structure
  - Current Projects
- Technical Strategy Area Highlights
  - Fundamental Research
  - Reactor Sustainability
  - International Reactors
  - Advanced Reactors and Methods

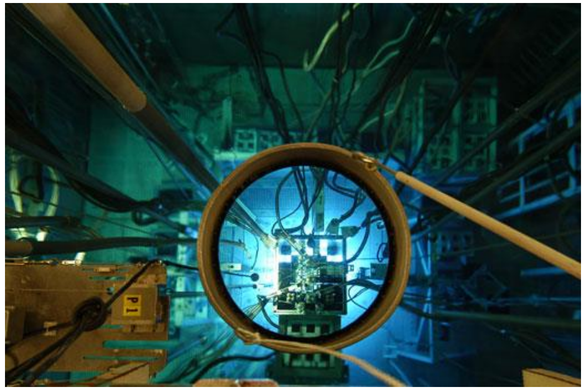


International Materials Research (IMR) Program Objectives

- International Materials Research enhances the understanding of the damage mechanisms in materials used in light and heavy water reactors. Research results lead to improved predictive models, provide inputs to aging management plans, and provide potential countermeasures that contribute to the safe, continued operation of plant components.
- IMR collaborates with other EPRI materials-related research programs, the Materials Aging Institute (MAI) at EDF, the U.S. Department of Energy (DOE), the U.S. Nuclear Regulatory Commission (US NRC), and international organizations to ensure that research projects and results reflect a wide range of nuclear technologies, operating conditions, and service environments.
- IMR is also actively involved in internal and external programs that support the identification and qualification of materials for advanced reactors, including non-light-water reactors.

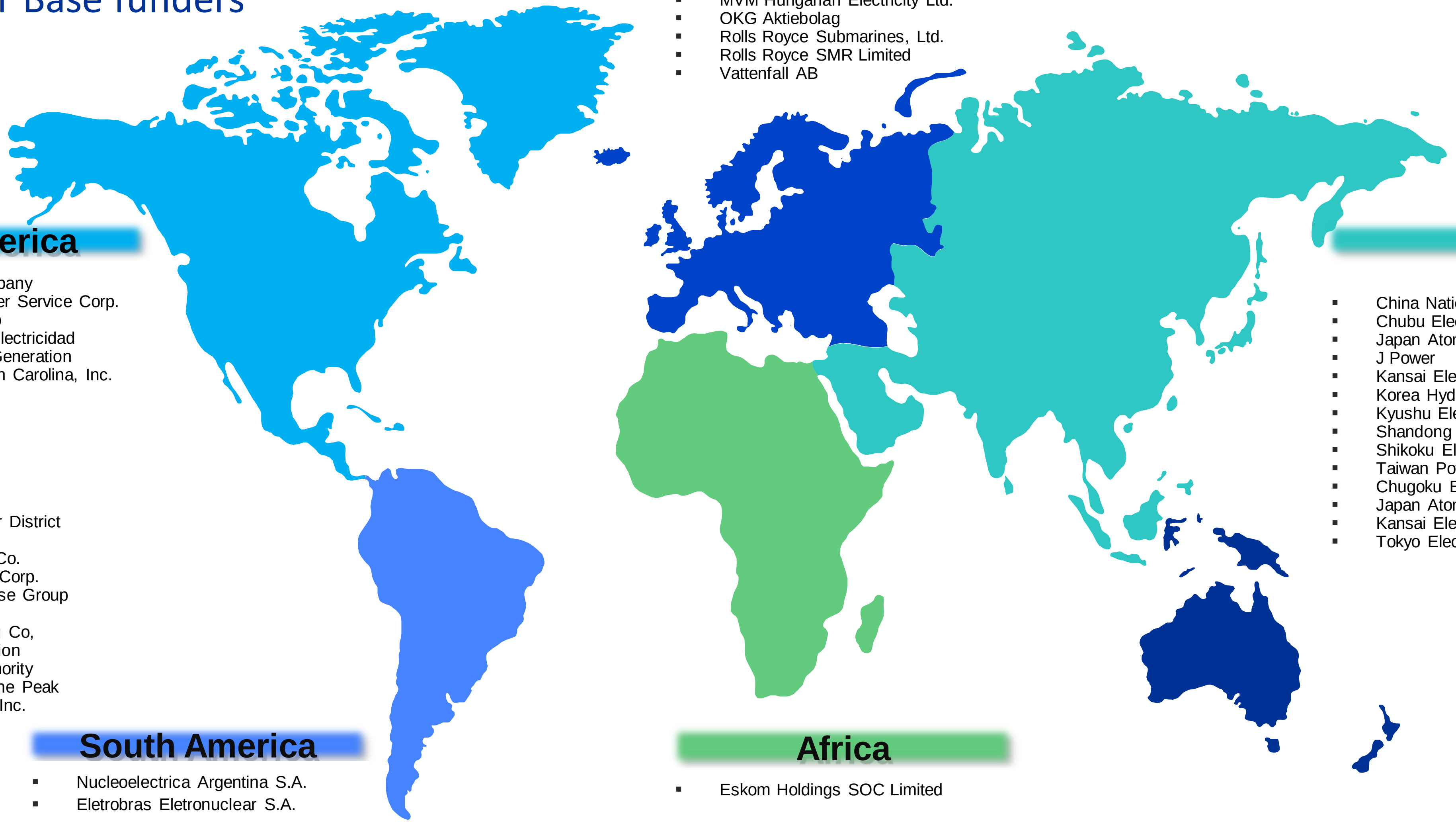






IMR Membership

IMR members are
Nuclear Sector Base funders



Europe

- Axpo Power AG
- CEZ A.S.
- Electrcite de France S.A.
- Foro de la Industria Nuclear Espano (FORO-CEN)
- Kernkraftwerk Goesgen-Daeniken AG
- Krsko
- MVM Hungarian Electricity Ltd.
- OKG Aktiebolag
- Rolls Royce Submarines, Ltd.
- Rolls Royce SMR Limited
- Vattenfall AB

North America

- Ameren Services Company
- American Electric Power Service Corp.
- CANDU Owners Group
- Comision Federal de Electricidad
- Constellation Energy Generation
- Dominion Energy South Carolina, Inc.
- Dominion Energy, Inc.
- DTE Electric Company
- Duke Energy Corp.
- Energy Harbor Corp.
- Energy Northwest
- Entergy Services, Inc.
- Evergy Services, Inc.
- Nebraska Public Power District
- NextEra Energy, Inc.
- Pacific Gas & Electric Co.
- Pinnacle West Capital Corp.
- Public Service Enterprise Group
- Southern Company
- STP Nuclear Operating Co,
- Talen Energy Corporation
- Tennessee Valley Authority
- Vistra Energy/Comanche Peak
- Xcel Energy Services, Inc.

Asia

- China National Nuclear Power
- Chubu Electric Power Co., Inc.
- Japan Atomic Power Company
- J Power
- Kansai Electric Power Co.
- Korea Hydro & Nuclear Power Co.
- Kyushu Electric Power Co., Inc.
- Shandong Nuclear Power Co., Ltd.
- Shikoku Electric Power Co., Inc.
- Taiwan Power Company
- Chugoku Electric Power Co., Inc.
- Japan Atomic Power Company
- Kansai Electric Power Co., Inc.
- Tokyo Electric Power Company Holdings

South America

- Nucleoelectrica Argentina S.A.
- Eletrobras Eletronuclear S.A.

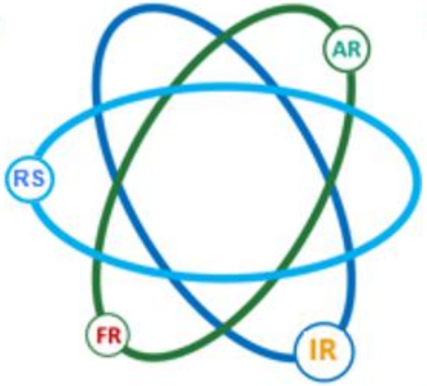
Africa

- Eskom Holdings SOC Limited

International Materials Research (IMR) Structure

Reactor Sustainability

- Age-dependent degradation mechanisr
- Materials behavior of AM components
- Materials harvesting projects



Advanced Reactors and Methods

- Materials degradation mechanisms, testing programs, and collaborations to support AR materials
- Advanced methods for materials qualification times and data set management

Fundamental Research

- Microstructural effects on mechanical properties
- Technologically-innovative approaches to support plant operations

International Reactors

- LTO of international reactor designs
- MDM, IMTs, research prioritization
- Support iGALL activities

IMR Leadership Team

- Exec. Sponsor: Henric Lidberg (Vattenfall)
- Chair: Otto Yong (OPG)
- Vice Chair: Vacant
- Program Manager: Jean Smith (EPRI)

IMR EPRI Staff

- Peter Chou, PhD
- Frank Gift
- Jared Smith, PhD
- Cem Topbasi, PhD

IMR Utility Members

- Expertise and/or interest in materials, testing methods, new reactors

IMR Current Projects by Materials Research Focus Area

MRFA 2 Stainless Steel Alloys
- Alloy Variability and IASCC in Stainless Steels
- Rapid Quantification of Irradiation Induced Microstructures by Deep Learning
- Irradiation Effects on Stabilized Stainless Steels
- Planning of Plant Materials Extraction
- Laser Annealing for Mitigation of IASCC Initiation
- Rapid Simulation of Void Swelling in VVER Internals
- Mitigation of CANDU CRD Cracking

MRFA 3 Nickel-Based Alloys
- LRO of Alloy 690 in LWR Components
- Role of GB Carbides on Crack Initiation in Alloy 600 and Alloy 182

MRFA 4 Low Alloy Steels
- Characterization of Environmentally-Assisted Cracking in CANDU Low-Alloy Steel Components

MRFA 5 Fatigue
- EAF Component Test
- EAF Water Chemistry Effects (KOH + B, KOH only)

MRFA 6 Wear
- PWR Wear Issues

MRFA 8 Water Chemistry and Mitigation
- Testing of Materials for KOH Qualification
- Development of More Rugged ECP Probe for BWRs
- Pt Gamma Ray Emissions for Verification of Noble Metal Deposition

MRFA 9 Repair and Replacement
- Additive Manufacturing for Large Forgings
- SCC and Fatigue Testing of DED Stainless Steel
- Byron AM Thimble Plugging Device

MRFA 10 Advanced Reactors and Methods
- AI for AR Materials Qualification
- Rapid Quantification of Irradiation-Induced Microstructures by Deep Learning
- Rapid and Standardized Assessment of Platinum Particle Size and Distribution in BWRs Using Machine Learning

MRFA 12 Tech Transfer, Databases, and Training
- Annual Materials Handbook Revision
- Computer-Based Training for IMR Products
- Interactive Materials Handbook
- Issue Management Tables for VVER/CANDU
- EPRI Materials Research Data Catalog
- Materials Degradation Matrix

EPRI

International Materials Research

- International Materials Research Technical Strategy areas focus on Fundamental Research, Reactor Sustainability, International Reactors, and Advanced Reactors and Methods.
- IMR supports the Materials Department Ageing Issue Cycle by developing and maintaining the Materials Degradation Matrix (MDM) and Issue Management Tables (IMTs)

Collect OE and Review Research Results

- Collect data from field reports and inspections results and assess the efficacy of the corrective actions (mitigation, repair, replacement).
- Updated research results from EPRI programs, technical literature, and conferences are reviewed by EPRI SMEs.

Materials Degradation Matrix

- The MDM reflects the state of knowledge of degradation mechanisms for materials and by reactor type.
- Materials Degradation Matrix (MDM) Revision 4 (3002013781; May 2018)
- **Revision 5 of the MDM is in progress for completion in 2023.**
- **Parallel activities to develop MDMs for LWR SMRs and ANLWR are being led by IMR.**

Evaluate Technical Gaps

- Review gaps from previous IMT revision (close, keep open, re-rank); define new gaps based on OE; utility members prioritize gaps.
- IMTs for PWRs, BWRs, VVERs will be reviewed after the completion of MDM Rev. 5.
- **IMTs for CANDU reactors are currently under development for publication in 2023.**

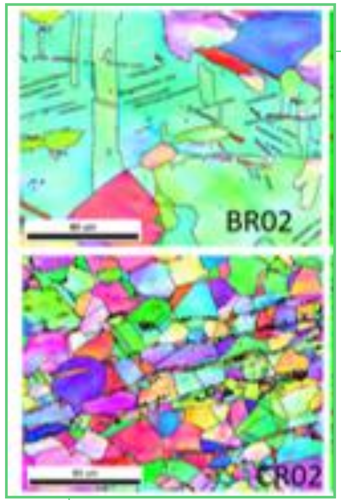
Technical Strategy Area: Fundamental Research

Fundamental Research

Conduct research on
- Microstructural effects on mechanical properties
- Technologically-innovative approaches to support plant operations

Correlating Microstructure to Mechanical Properties

- IMR supports Issue Programs by conducting derivative research to elucidate microstructural contributions to mechanical testing results.
- Work to support ASME Code Case N-889 *Reference Stress Corrosion Crack Growth Rate Curves for Irradiated Austenitic Stainless Steels in Light Water Reactors* was supported by IMR.



Key Variables in IASCC Susceptibility

- Many IASCC crack growth rate test segments have been evaluated and categorized to support development of IASCC CGR disposition curve development. Some specimens tested in the same environment under similar conditions showed statistical differences in CGR.
- Microstructural characterizations including light optical microscopy (LOM), scanning electron microscopy (SEM), transmission electron microscopy (TEM), electron backscatter diffraction (EBSD), and atom probe tomography (APT) as well as tensile and microhardness testing are underway reconcile the difference in CGR behavior.
- In one pair of specimens, the ferrite content and the orientation of the ferrite relative to the direction of crack advance were likely contributors to the difference in CGR.

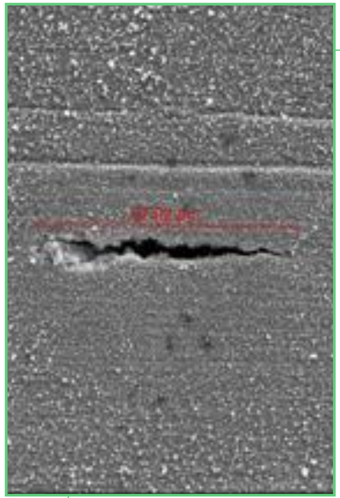
Technical Strategy Area: Fundamental Research

Fundamental Research

- IMR staff submit proposals for EPRI Technology Innovation (TI) funding and collaborate on external funding opportunities such as DOE Rapid Turnaround Experiments (RTEs)
- IMR research supports Nuclear Sector initiatives

Supporting Plant Operations

- Projects related to the development of more-rugged ECP probes for BWRs and the use of Pt gamma ray emissions for verification of noble metal deposition.
- Advanced characterization of plant components to support utility component failure analyses.



KOH Qualification

- IMR has performed crack initiation and crack propagation testing on stainless steels, irradiated stainless steels, and nickel-based alloys in both KOH and LiOH water chemistries to support the Nuclear Sector program to qualify KOH for pH control in Western-style PWRs.
- Absolute rates are not the key results, since tests have been accelerated to induce results and emphasize water chemistry effects.
- No statistical difference in crack initiation times or crack growth rates were observed in the two environments
  - Testing of non-irradiated stainless steel in hydrogenated crevice chemistry environments continues

Technical Strategy Area: Reactor Sustainability

Reactor Sustainability

Conduct research to address

- Age-dependent degradation mechanisms
- Materials behavior of AM components
- Materials harvesting projects

Materials Harvesting

- Harvested materials from operating and decommissioned reactors are the most representative source for characterizing the end-of-life properties of reactor internals components.
- EPRI has participated in International Harvesting Workshops co-hosted by NRC and NEA to connect with the global community to prioritize research objectives and to coordinate harvesting opportunities.
- Regulators from many countries have shown a keen interest in harvesting and recognize the value of these materials for extending the technical bases for ageing management strategies.
- Decommissioned plants also provide an opportunity to perform NDE activities.

Low Alloy Steel Thermal Embrittlement

- Ringhals 2 and Indian Point 2 pressurizer vessel and welds
- Perform visual inspection of thermal shield flexures according to MRP-227 and Westinghouse TB-19-5 and UT exam of TSSBBs to support industry experience related to baffle-former bolt failures and TS component degradation

Technical Strategy Area: Reactor Sustainability

Reactor Sustainability

- IMR collaborates internally with other EPRI programs such as MRP, WRTC, ANT
- Externally, IMR works with other research organizations such as MAI, US DOE, US NRC, and with utilities.

Advanced Manufacturing

- Internal collaboration between IMR, WRTC, and ANT to develop a project to characterize stress corrosion cracking and fatigue life of DED Type 316 stainless steel.
- External collaboration between EPRI and MAI (and its members) to further understand degradation behavior of AM materials.

Byron AM Thimble Plugging Device

- March 2020: Constellation installed a Type 316L SS AM (LPBF) TPD in Byron Unit 1
- September 2021: AM-TPD removed after 1st fuel cycle, visually inspected then re-installed
- March 2023: AM-TPD will be removed after 2nd fuel cycle, visually inspected then re-installed (if Satisfactory Condition)
- September 2024: AM-TPD removed after 3rd fuel cycle and will be made available for Post-Irradiation Examination (PIE) to determine effects of 4.5 years of radiation and operating temperature exposure on the 316L SS LPBF material

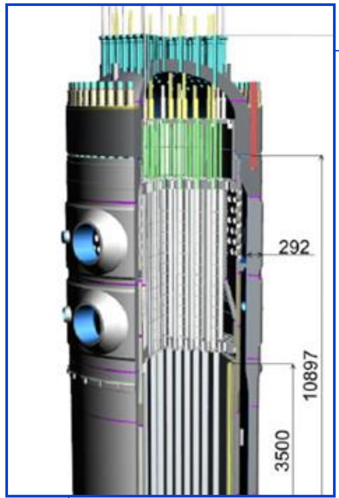
Technical Strategy Area: International Reactors

International Reactors

- MDM, IMTs, research prioritization
- LTO of international reactor designs
- Support iGALL activities

Development of VVER and CANDU IMTs

- The incorporation of CANDU (Rev. 3; 2013) and VVER (Rev. 4; 2018) components into the Materials Degradation Matrix has facilitated IMR's ability to support LTO of international reactor designs.
- Subsequent development of IMTs prioritizes research efforts and enables focus on near-term issues affecting long-term operations.



Irradiation Effects on Stabilized Stainless Steels (VVERs)

- Irradiation-assisted stress corrosion cracking (IASCC) has been observed in reactor vessel internals (RVI) in western type boiling water reactors (BWRs) and pressurized water reactors (PWRs). In eastern type PWRs (VVERs) IASCC has been reported in only a few cases.
- The main differences between the PWRs of western and eastern designs are the RVI construction materials (stabilized SSs, no Ni-based alloys) and operational environment (water chemistry; temperature).
- High-reliability CGR data on IASCC of Type 321 austenitic stainless steel irradiated up to 11.4 dpa in an operating VVER satisfy the PWR disposition reference curve given in ASME Section XI IASCC Code Case N-889.

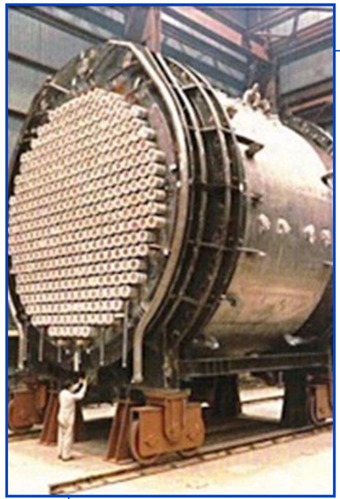
Technical Strategy Area: International Reactors

International Reactors

- IMR staff participate in CANDU Owners Group (COG) Steels and Steam Generator Integrity working group meetings and have participated in COG SCC workshops
- IMR staff support the iGALL Mechanical Working Group (WG1)

Long-Term Operation of International Reactors

- EPRI's international members have many different regulatory obligations for long-term operations.
- The high-priority issue gaps differ by reactor design; although, some common themes exist.
- Some reactor-specific projects have underlying mechanistic application to other reactor designs.



CANDU Calandria Relief Duct (CRD) Cracking

- Significant operating experience related to CRD cracking has been observed since 2005.
  - Root cause: Chloride-SCC in weld HAZ exacerbated by iron contamination
- Current IMR project is a lab-to-pant approach to
  - Study the mechanism of cracking (relationship to pitting as a precursor)
  - Identify the domains of SCC susceptibility using electrochemical testing
  - Determine futures steps for monitoring via CRD surface sampling techniques and mitigating

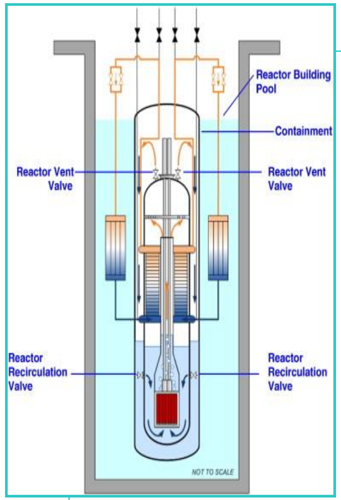
Technical Strategy Area: Advanced Reactors & Methods

Advanced Reactors and Methods

- Materials degradation mechanisms, testing programs, and collaborations to support AR materials
- Advanced methods for materials qualification and data set management

Materials Characterization Needs for Future Fleet

- IMR is developing a Materials Degradation Matrix for advanced non-light water reactors (ANLWRs)
- The identification of component material classes and degradation mechanisms also supports EPRI efforts to support the development of RIM programs for ANLWRs
- Collaboration will be key to successfully test and qualify materials for use in advanced reactors; IMR has been actively coordinating with developers, universities, and DOE



Materials Degradation Matrix for ANLWRs

- Material Property Assessment and Data Gap Analysis for the Prospective Materials for Molten Salt Reactors — 3002010726
- Material Property Assessment and Data Gap Analysis for Sodium-Cooled Fast Reactors — 3002016949
- Material Property Assessment and Data Gap Analysis for the Prospective Materials for Very High Temperature Reactors and Gas-Cooled Fast Reactors — 3002015815
- Materials Property Assessment and Gap Analysis for Lead-Cooled Fast Reactors — 3002016950

Advanced Reactor Materials Development Roadmap
Addresses extension of ASME Code property data and mechanical, corrosion, and irradiation property data
3002022979 (2021)

Materials Degradation Matrix for Advanced Non-Light Water Reactors
(beginning in 2023)

- Issue Management Tables for Molten Salt Reactors
- Issue Management Tables for Sodium-Cooled Fast Reactors
- Issue Management Tables for VHTRs and Gas-Cooled Fast Reactors
- Issue Management Tables for Lead-Cooled Fast Reactors

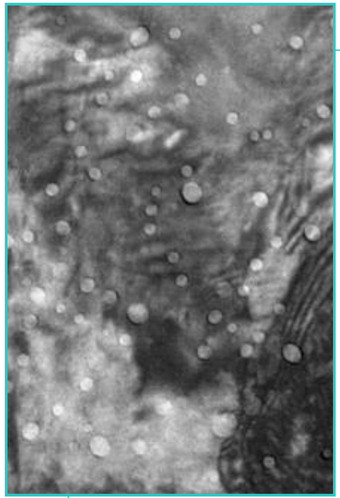
Technical Strategy Area: Advanced Reactors & Methods

Advanced Reactors and Methods

- Materials degradation mechanisms, testing programs, and collaborations to support AR materials
- Advanced methods for materials qualification and data set management

Advanced Methods for Materials Characterization

- Machine learning (ML) provides rapid detection and quantification of features in images and videos.
- IMR's ML approach is based on convolutional neural networks (CNNs), which uses supervised learning
- Objective is universal software for automated defect detection and analysis of images to reduce the time for qualification of new materials



Rapid Quantification of Irradiation-Induced Microstructures

- Electron microscopy techniques are widely used to identify defects, such as dislocation loops and cavities, in materials. The key challenge is to determine the number density and size distribution of each defect type.
- EPRI is employing machine/deep learning methods to develop a combined framework for automatic detection and analysis of nanocavities and estimate void swelling accurately.
- Current project on quantifying void swelling has resulted in very good size predictions with some underestimation of cavity density. However, overall swelling predictions are accurate.
- Applying same ML approach to a more rapid and standardized assessment of Pt particle size and distribution in BWRs.

IMR Interactions with NRC

Topical Meetings

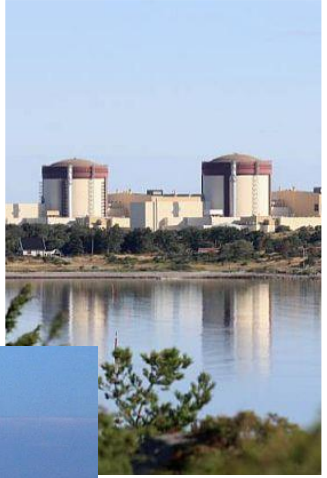
- Monthly Materials Research Pathway meetings
  - NRC, DOE LWRS, EPRI
  - Coordinating the revision to the Joint Materials Roadmap
- NRC-DOE-EPRI ANLWR Materials, Chemistry, and Component Integrity (MCCI) meetings
  - Share information, data, and knowledge of materials and component integrity research activities.
  - Enhance common understanding of technical issues impacting safety.
  - Address areas of potential knowledge gaps useful for engineering assessments.
- Regular Materials Harvesting meetings
  - Discussion harvesting opportunities, ongoing projects, and prioritizations

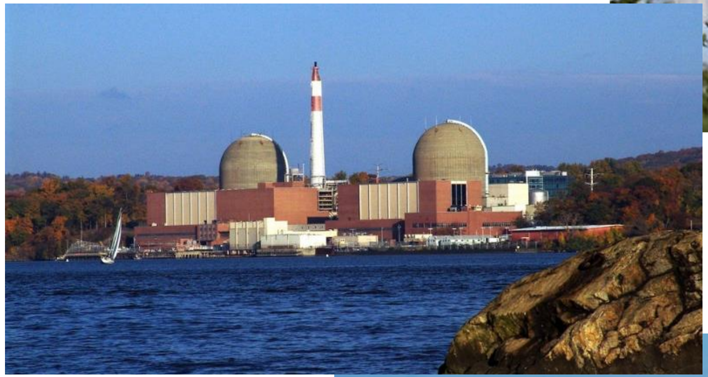
Project Status Meetings

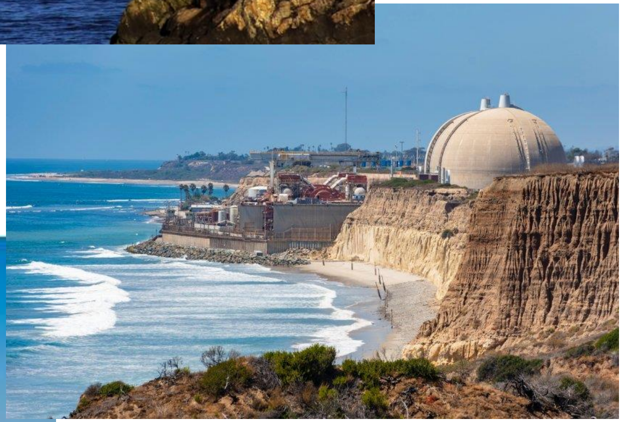
- Monthly SMILE coordination meetings
  - EPRI staff with NRC Research staff discuss status of SMILE harvesting project
- NEA FIDES coordination meetings
  - DOE-NRC-EPRI as core group for JEEP for in-pile materials characterization
- Nickel-based Alloy Long-Term Aging meetings
  - Regular interactions on joint projects on long-term aging of NBAs

Summary

- International Materials Research enhances the understanding of the damage mechanisms in materials used in light and heavy water reactors and supports EPRI members by providing technical basis data for developing aging management strategies. *Fundamental Research*
- IMR performs research to support Nuclear Sector Base members across the existing fleet of PWRs, BWRs, CANDUs, and VVERs. *Reactor Sustainability*
- IMR collaborates with international organizations to ensure that research projects and results reflect a wide range of nuclear technologies, operating conditions, and service environments. *International Reactors*
- IMR is actively involved in internal and external programs that support the identification and qualification of materials for advanced reactors, including non-light-water reactors. *Advanced Reactors and Methods*







Together…Shaping the Future of Energy®

NDE Program Review

ACRS Information Exchange

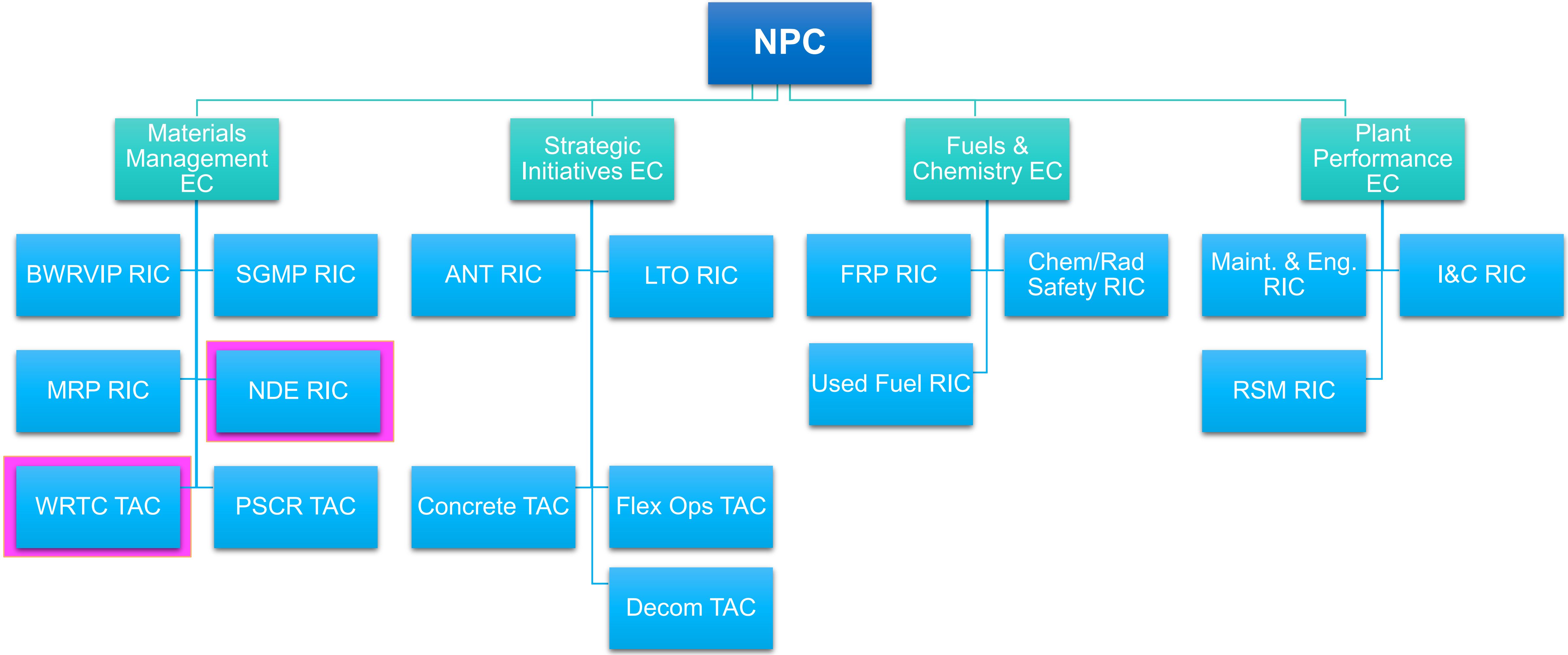
Robert Grizzi, Program Manager
Plant Support / NDE

Bethesda, MD - White Flint
March 27, 2023

Content

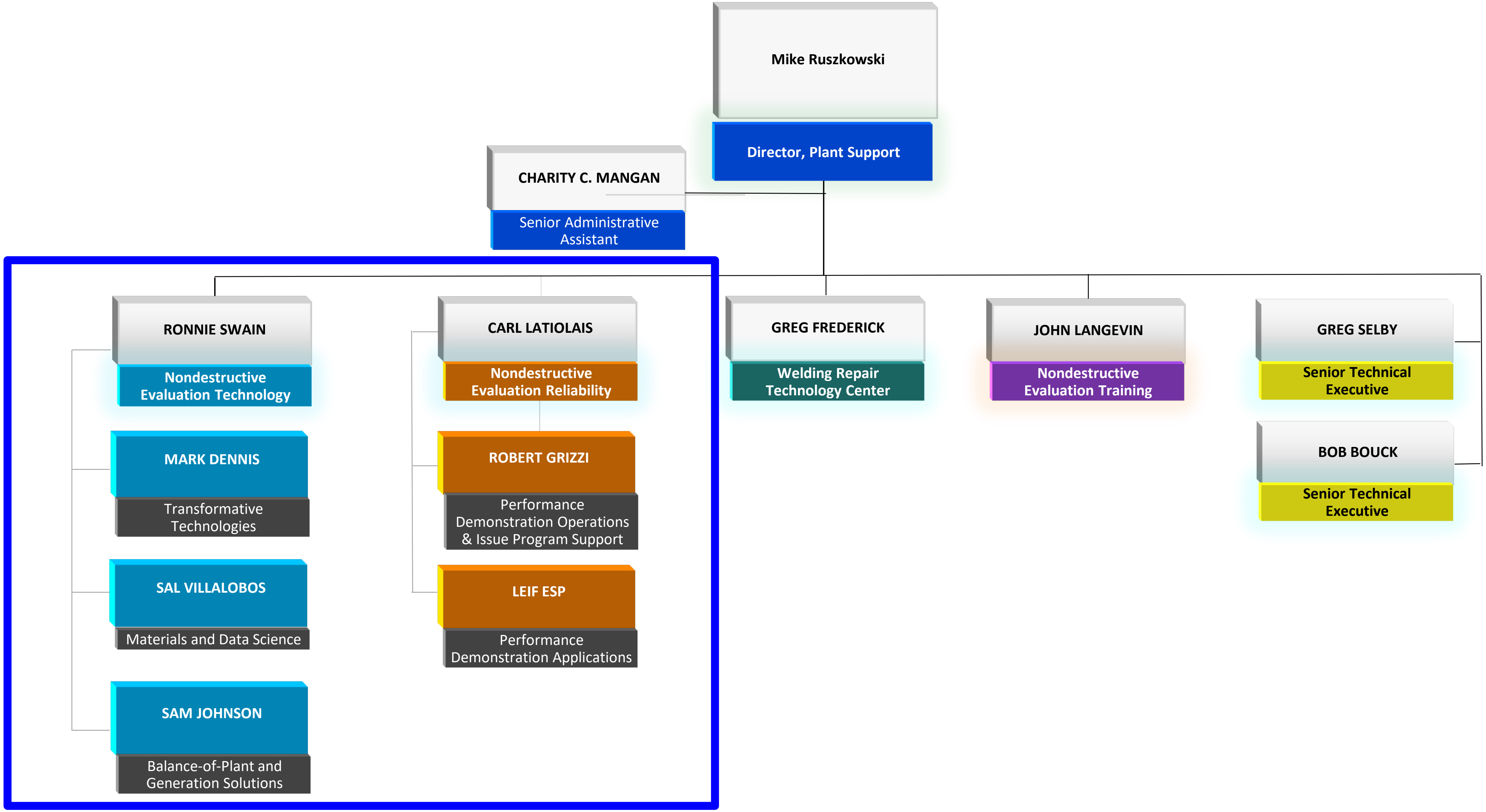
- NDE Program Advisory Structure
- NDE Program Organizational Structure
- NDE Program Members & Participants
- 2023 Research Focus Areas
- Artificial Intelligence & Machine Learning for NDE Data
- Virtual Flaws
- Virtual Reality for NDE
- Optimization of NDE Examination Requirements
- NDE LTO/Balance of Plant Research
- NDE Fundamental and Strategic Research
- NDE Training Program
- NDE Staff Engagement in ASME Code Committees

NDE Program Advisory Structure



Revised: 3/8/2022

Plant Support Organization Chart



EPRI

NDE Program Members & Participants

- Argentina
- Brazil
- Canada
- China (CNNP)
- Czech Republic
- France
- Hungary
- Japan
- Korea
- Mexico
- Romania
- Slovenia
- South Africa
- Spain
- Switzerland
- Taiwan
- United Arab Emirates
- United Kingdom
- United States

- Flour Marine Propulsion
- Knolls Atomic Power Labs
- Idaho National Labs
- Rolls-Royce Submarines
- Rolls-Royce SMR
- Tecnatom

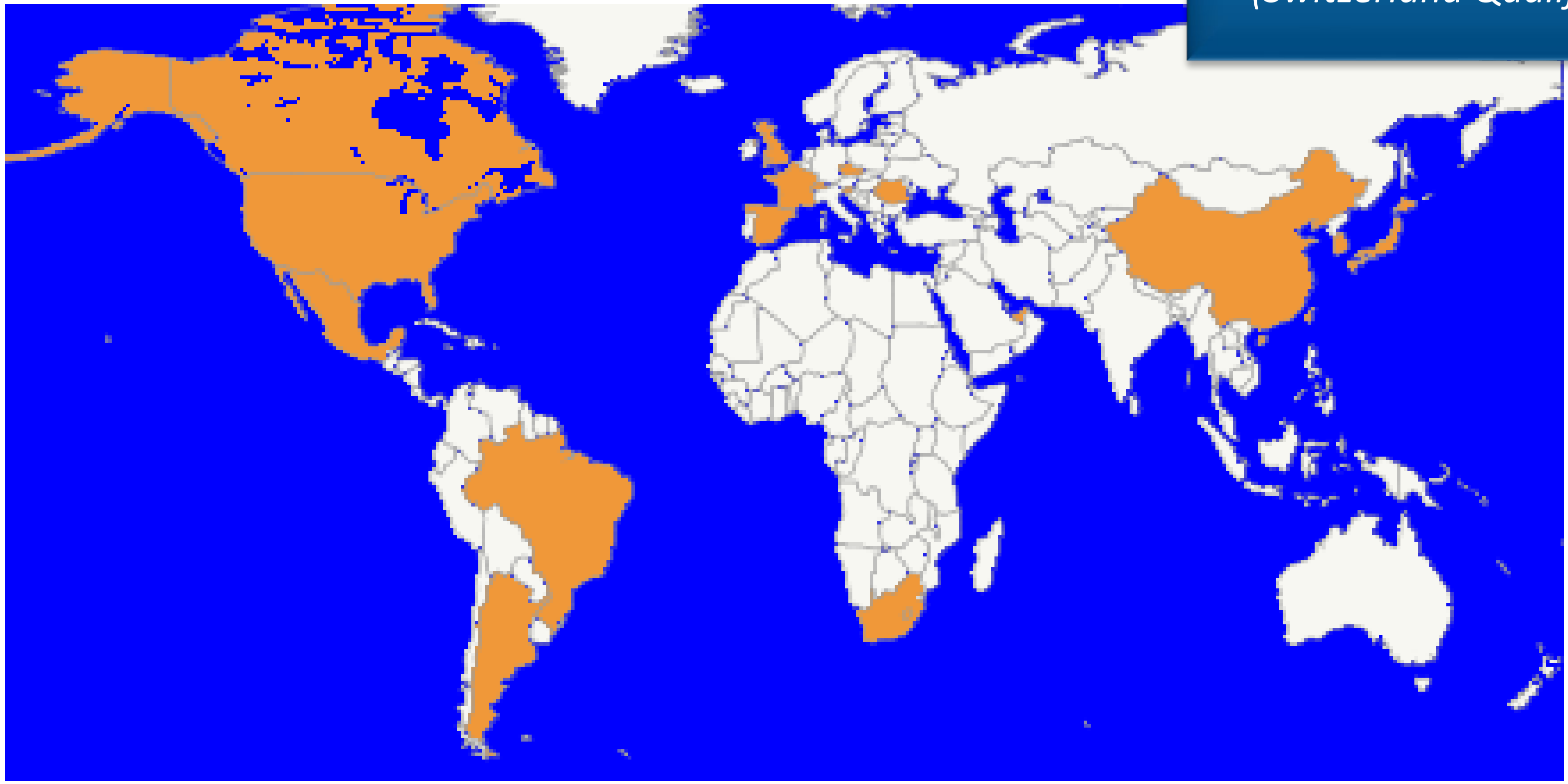
Strategic Alliances

CRIEPI
(Japan Qualification Body)

KHNP Research
(Korea Qualification Body)

SQC
(Sweden Qualification Body)

QST
(Switzerland Qualification Body)



NDE

2023 Research Focus Areas

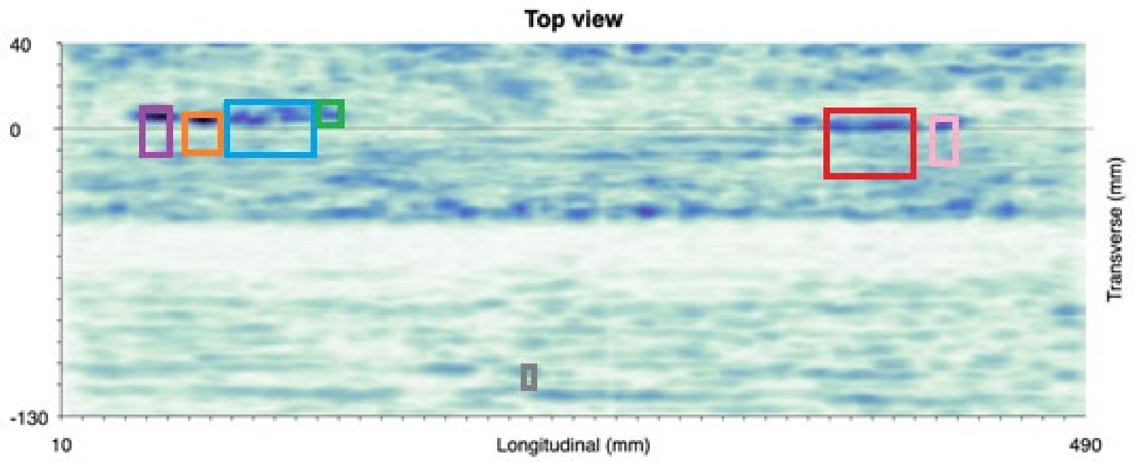
Typically, the annual workplan includes 50 - 70 separate projects

There are over 600 NDE Program products available

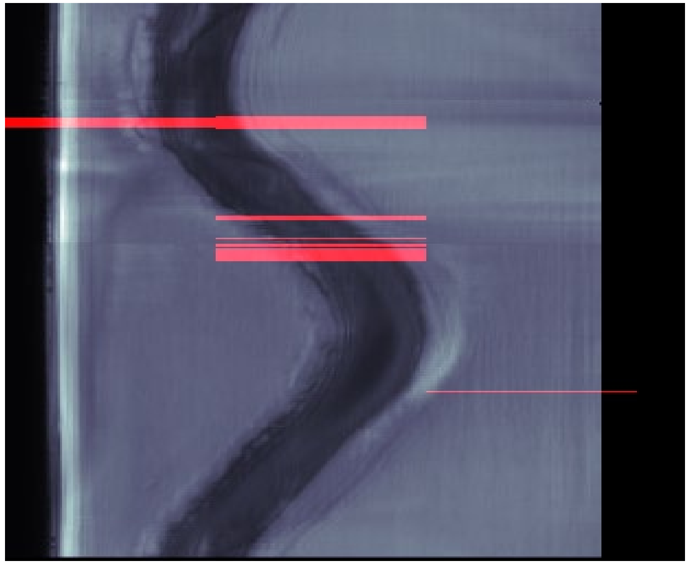
- RFA 1 — Cast Stainless Steel
- RFA 2 — Codes and Standards
- RFA 3 — Performance Demonstration
- RFA 4 — Advanced NDE Methods
- RFA 5 — Balance of Plant and Generation
- RFA 6 — Risk Informed Methodologies
- RFA 7 — NDE Training
- RFA 8 — Material Characterization and Real Time NDE
- RFA 9 — Efficiency and Optimization
- RFA 10 — Machine Learning and Artificial Intelligence for NDE

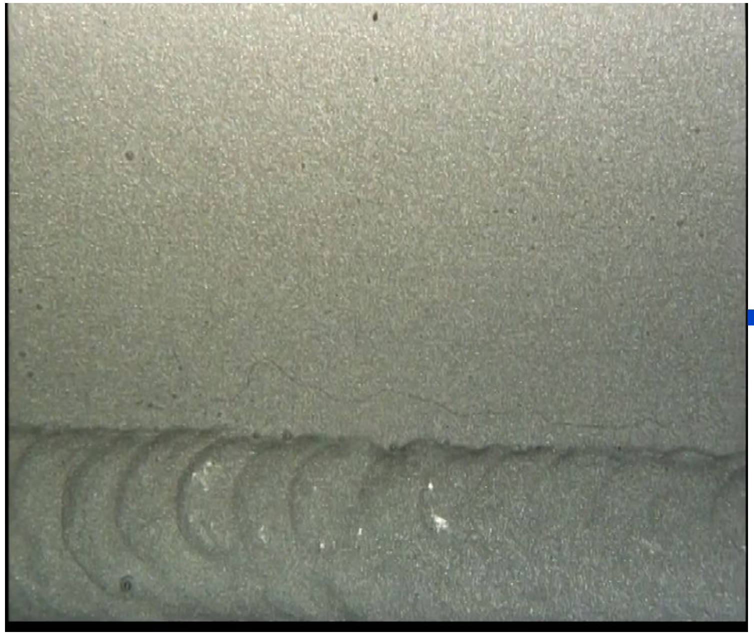
Artificial Intelligence & Machine Learning for NDE Data

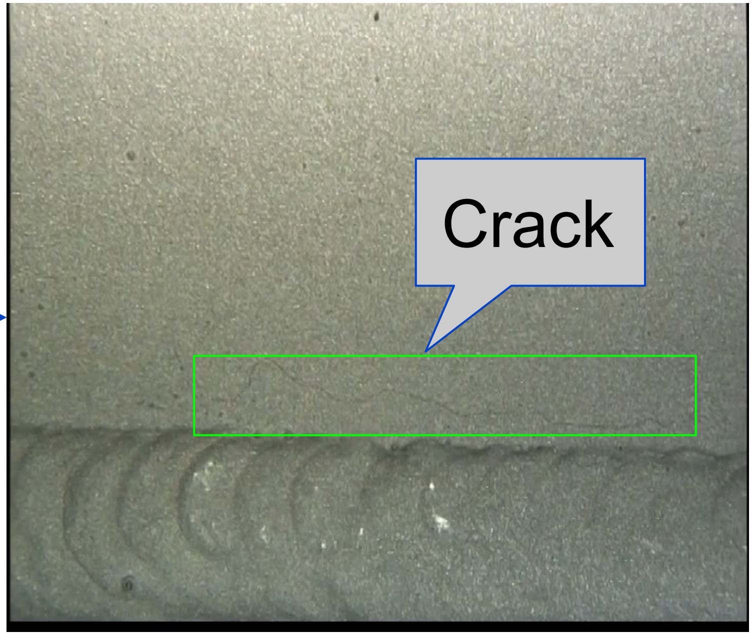
Digitized UT Data – Dissimilar Metal Weld Examination



Digitized UT Data – RPV Upper Head Penetration Tube Examination







Recorded Video of EVT-1 Examination Data – Post Processing

AI Case Study for RVUH

Pilot Application

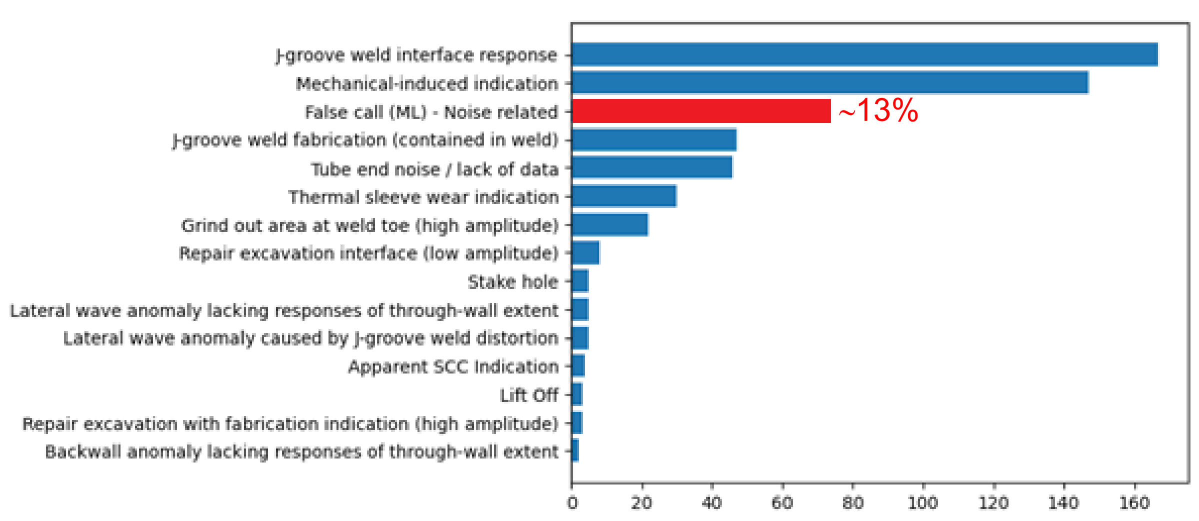
- 78 penetrations evaluated using AI
- AI flagged **~2%** for review
- Average of **~4min** per penetration
- All flagged regions were categorized
  - High weld interface disturbances & mechanically induced indications account for most calls (~56%)
  - Only **~13%** of flags due to noise
- The model successfully **flagged all SCC locations**

AI-assisted analysis yielded same results as the one from the qualified vendor

Amount of Data Requiring Review

Pre-AI		Post-AI	
4.4	miles	463	feet
7.0	km	141	meters

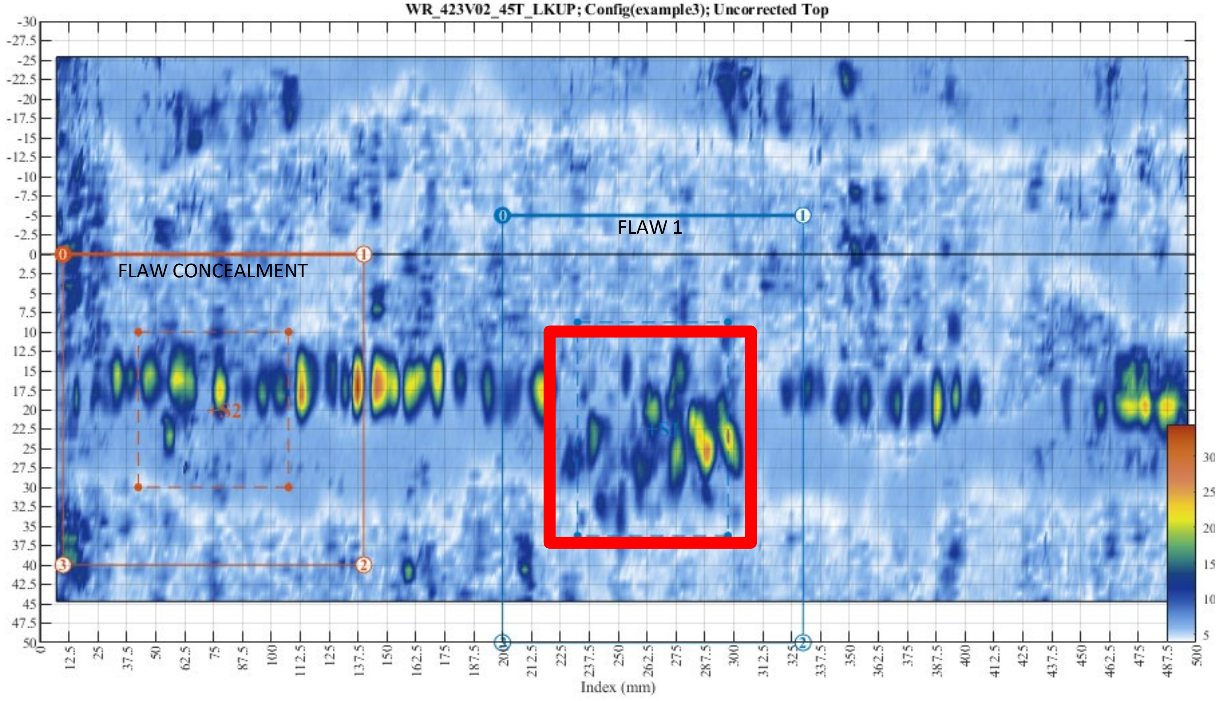
All values are approximate



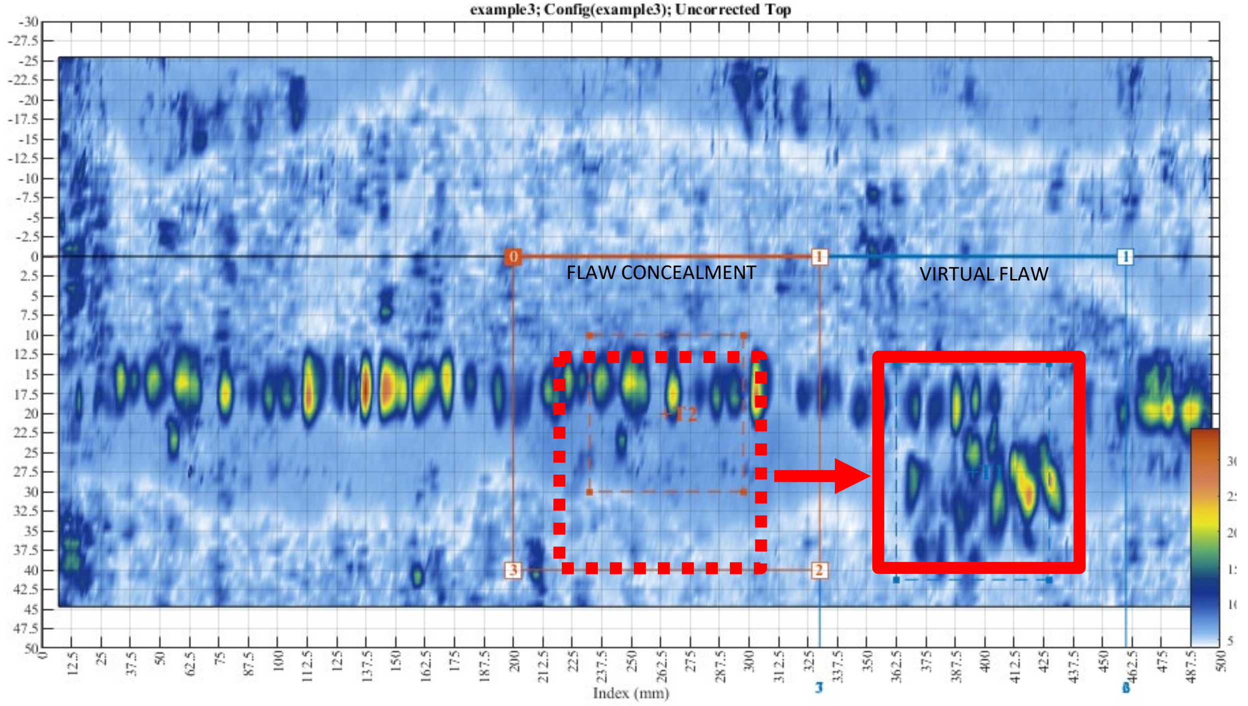
Virtual Flaws - Creation in UT Data

- Virtual Flaw = a real implanted flaw where UT data has been collected and recorded (digitized)
- Synthetic Flaw = a flaw created from modeling and digital data, where no “real” flaw existed
- Target flaw - Carbon steel pipe weld mockup, circumferentially oriented flaw, scanned with a 45° transverse UT probe

LKUP; UNCORRECTED TOP; BEFORE

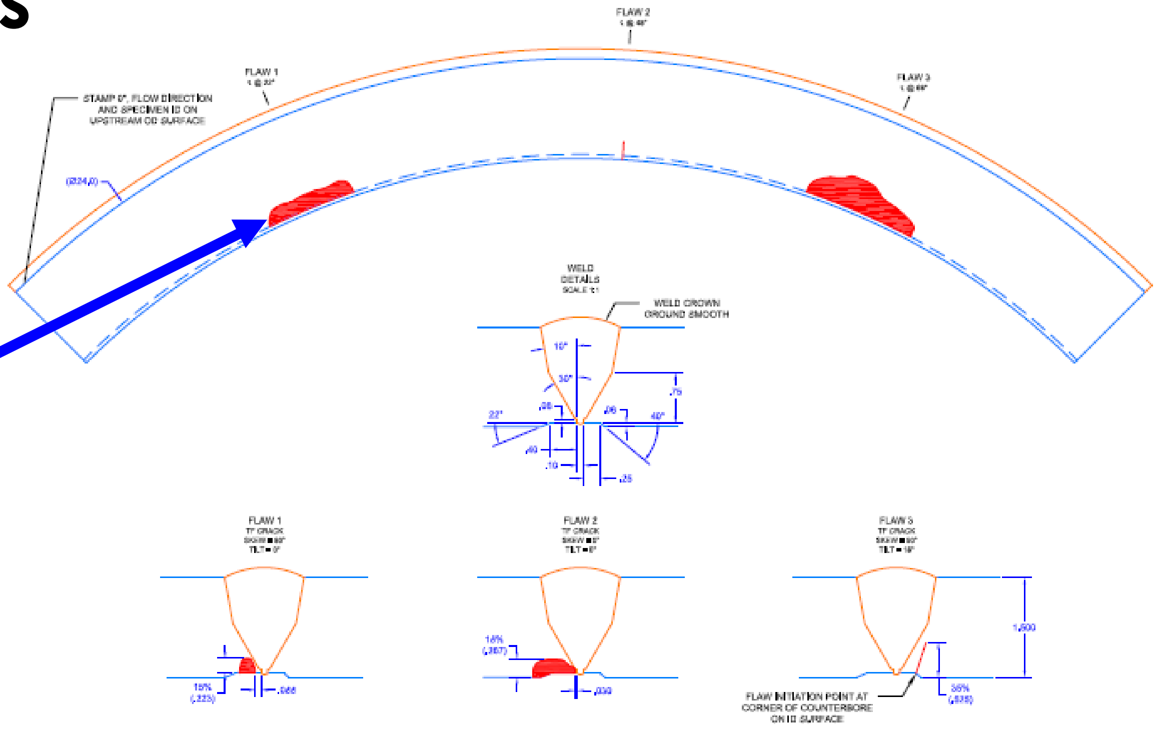


LKUP; UNCORRECTED TOP; AFTER



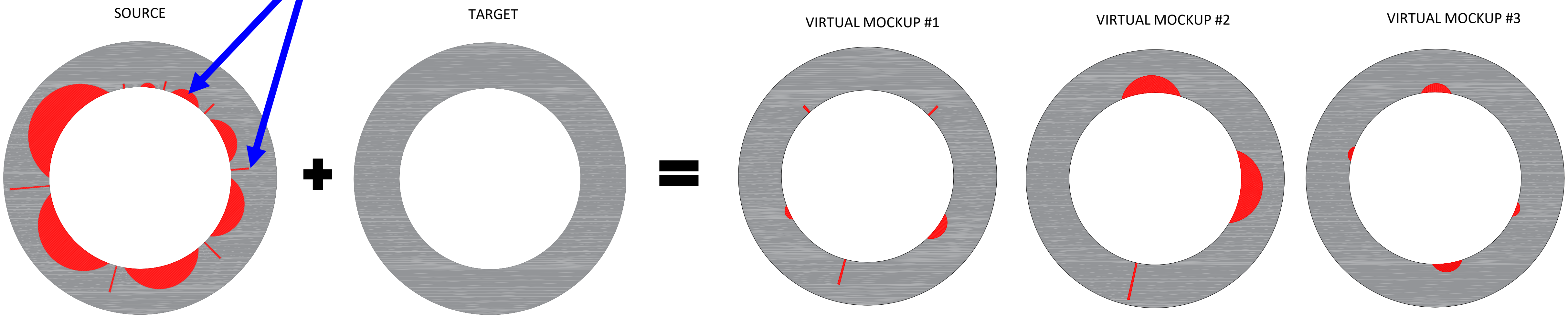
Virtual Flaws - Process and Benefits – In a Nutshell

Standard / Normal Specimen Design



Specimen Design for Virtual Flaws

Implanted Flaws



Virtual Reality Technology for NDE

Impetus

- New tools and modernized knowledge transfer/retention methods need to be developed to facilitate counteracting the industry's loss of knowledge base and experience through utility personnel attrition. As new resources backfill these voids, experience and knowledge transfer is quintessential to sustaining a safe, efficient, and viable industry. Using modern day, proven technologies we can effectively execute on knowledge transfer and retention by providing the level of training necessary to bring new or unfamiliar utility staff up to speed, quickly, in support of both the operating and future Nuclear fleet.

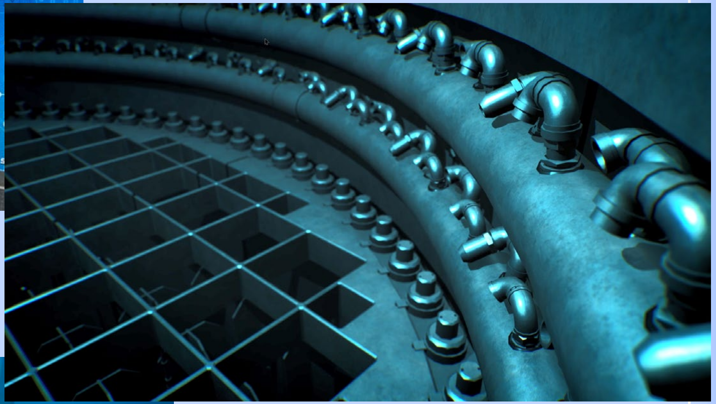
Current and Ongoing Research

- NDE, MRP, & BWRVIP all have VR environments in use and continue to enhance/develop them for NDE inspection activities

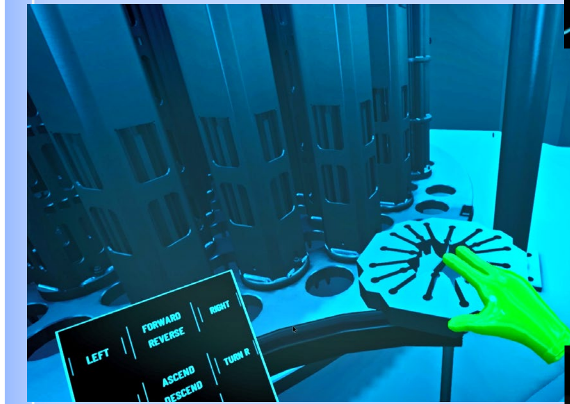
Value to Industry

- Offers the most realistic experience (in the absence of physical access) for the purposes of plant design and inspection familiarization, formal training, OTJ training, and pre-job briefings; as well as immediate and unlimited access to the VR environment at utility sites
- Promotes/facilitates effective internal communications through visualization of plant design and access challenges
- Minimal investment (~$3000 per system)
- Available to all Materials Program Members on Member Center

(BWRVIP) BWR Internals

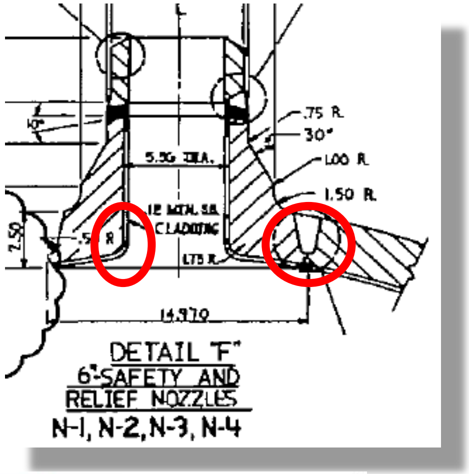


(MRP) PWR Internals



(NDE) WEC 4-Loop Containment

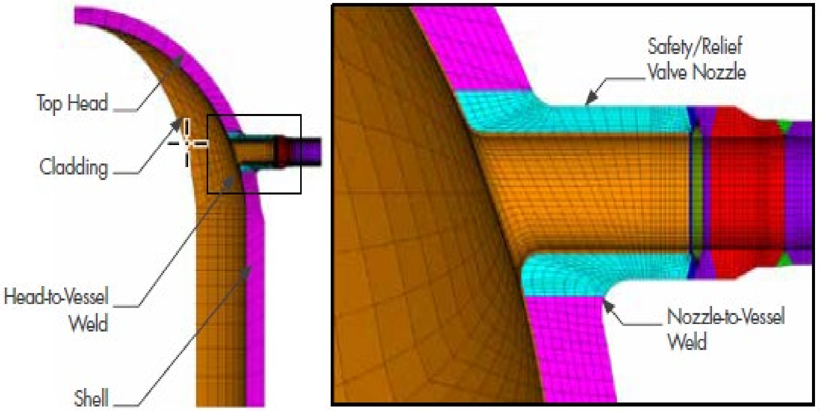
Optimization of NDE Examination Requirements



Industry leading utilities piloted the implementation of a series of EPRI NDE technical reports establishing the technical bases for optimizing inspection intervals of mandatory ASME component examination requirements, paving the way for other industry members to follow.

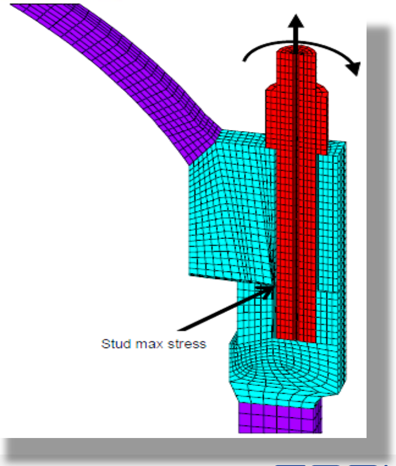
Highlights of Implementation

- Used the NRC Request for Alternative process
- First-of-a-Kind applications utilizing PFM as a cornerstone of the analysis
- SERs received for all pilot utilities
- SERs allowing for inspection intervals up to 30 years
- ASME Code actions will leverage Technical Bases and SERs
- EPRI has compiled a Lessons Learned document to aid in future submittals



Benefits

- Maximize overall plant safety by focusing resources where they are needed; on higher valued examinations
- Minimize health & safety risk profile of plant personnel by reducing unnecessary work activities
- Potential, significant dose savings (per unit) is on the order of multiple man-rem years
- Potential, significant cost savings



Optimization of NDE Examination Requirements

EPRI Technical Basis Report	Pilot Utility / Units for FOAK Submittals to the NRC
EPRI Report 3002014590, Technical Bases for Inspection Requirements for PWR Steam Generator Feedwater and Main Steam Nozzle-to-Shell Welds and Nozzle Inside Radius Sections	Southern Nuclear Operating Co. (SER) Vogtle Unit 1,2
EPRI Report 3002014590, Technical Bases for Inspection Requirements for PWR Steam Generator Feedwater and Main Steam Nozzle-to-Shell Welds and Nozzle Inside Radius Sections & EPRI Report 3002015906, Technical Bases for Inspection Requirements of PWR Steam Generator Primary Nozzle-to-Shell and Pressure Vessel Welds	Dominion Energy (SER) Millstone Unit 2
EPRI Report 3002015905, Technical Bases for Inspection Requirements of PWR Pressurizer Nozzle-to-Shell and Pressure Vessel Welds	PSEG (SER) Salem Unit 1,2
EPRI Report 3002018473, Technical Bases for Examination Requirements for Class 2 BWR Heat Exchanger Nozzle-to-Shell Welds; Nozzle Inside Radius Sections; and Vessel Head, Shell, and Tubesheet-to-Shell Welds	Exelon (SER) Limerick Unit 1,2
EPRI Report 3002012966, Evaluation of Basis for Periodic Visual Examination of Accessible Areas of Reactor Vessel Interior per Examination Category B-N-1 of ASME Section XI, Div. 1	Constellation (SER) Byron Unit 1,2 Braidwood Unit 1,2 Calvert Cliffs Unit 1,2 R.E. Ginna
EPRI Report 3002014589, Technical Basis for Optimization of the Volumetric Examination Frequency for Reactor Vessel Studs	Duke Energy (SER) McGuire Unit 1,2 Catawba Unit 1,2 Brunswick Unit 1,2 Shearon Harris

NDE LTO/Balance of Plant Research

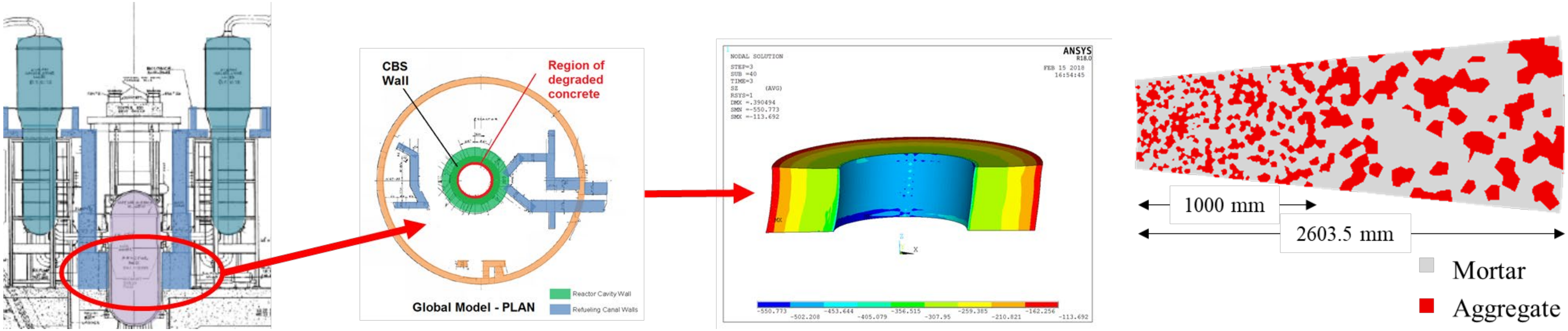
- **NDE on Carbon Fiber Reinforced Polymer (CFRP) Repair**
  - Increasingly being used to rehabilitate piping in Safety and non-Safety-Related applications
  - NDE techniques to examine the pipe through CFRP were <u>not</u> available
  - EPRI has built mock-ups using field removed corroded pipe
    - Demonstrated NDE Dynamic Response Spectroscopy and Pulsed ET technologies
  - Research continuing in 2023

- **Guided Wave for Tank Inspections**
  - Draining tanks requires disabling safety systems and is not always practical; Using divers is expensive and problematic
  - **Research Question:** Can License Renewal inspection commitments be satisfied from outside of the tank using GW?
  - Collaboration with PNNL modeling GW on Hanford Project tanks
    - Transfer learnings to the existing commercial fleet

NDE LTO/Balance of Plant Research

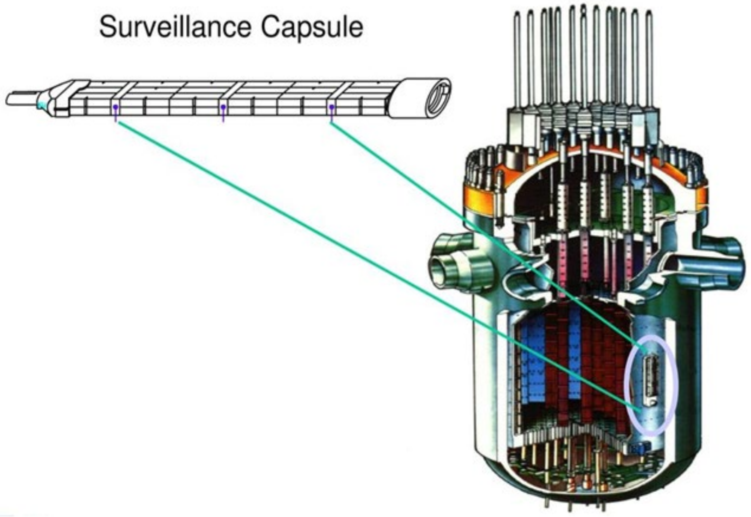
Irradiation Damage in Concrete Bio-Shields

- Neutron irradiation from the reactor vessel can cause swelling of aggregates and changes in physical properties
- EPRI has published 10 reports on irradiation effects on concrete starting in 2012, including 3 reports giving a methodology and example structural analyses in 2018
- Currently EPRI is working with Nagoya University and University of Tokyo on comparison analyses of design basis accident loading using the EPRI finite element methodology and the Japanese rigid body spring method modeling approach. The results will be published 2023.



NDE Fundamental and Strategic Research

- **NDE of irradiated surveillance capsules**
  - **Issue:** Limited number of capsules as plants age
  - Can radiation and aging effects be measured with NDE to reduce/eliminate costly destructive analysis processes?



- **Early Research on NDE for Additive Manufacturing**
  - **Issue:** 3D Printing and other AM methods will combine materials with different physical properties. How will this affect current volumetric testing technologies?
  - EPRI NDE and Welding Repair Technology Center are collaborating to refine AM methodologies and to document effective examination approaches

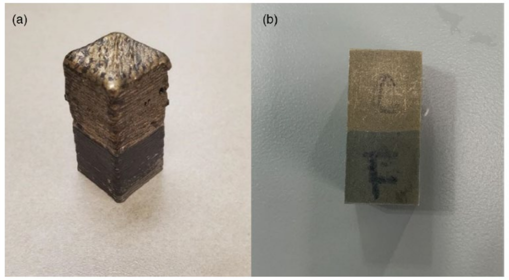
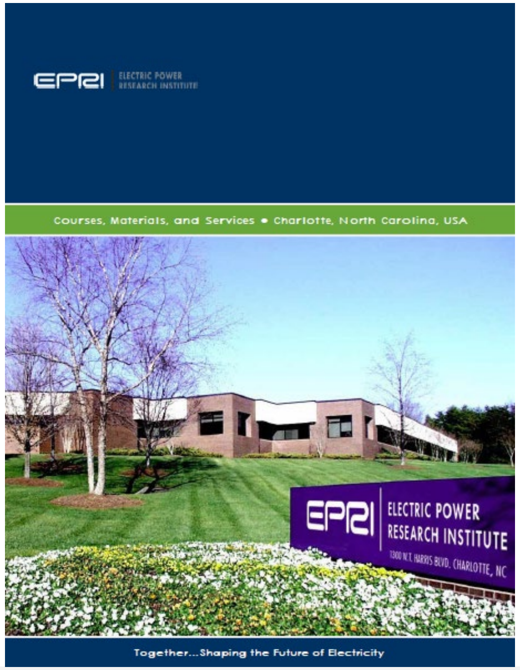


Figure 20. Small bimetallic coupon of stainless steel and copper alloy, photographed (a) as received and (b) after machining

2023 NDE Training Program - Schedule of Classes

Course	Dates	Location
NDE for Engineers	January 16-20	EPRI - Charlotte
Visual Examination Level II	February 20-24	EPRI - Charlotte
Ultrasonic Examination of Austenitic Stainless Steel Pipe Welds for Cracking	May 15-19	EPRI - Charlotte
Visual Examination Level III	June 12-16	EPRI - Charlotte
Boric Acid Corrosion Control - Visual Examination Limited VT-2	July 11-12	EPRI - Charlotte
Ultrasonic Examination Level III	July 17-21	EPRI – Charlotte
Concrete NDE Workshop	July 18 - 20	EPRI - Charlotte
Visual Examination Level II	August 14-18	EPRI - Charlotte
NDE for Engineers	September 12-14	EPRI - Charlotte



2023 NDE Training Calendar 2023

MO	M	T	W	T	F	S	S	WK	MO	M	T	W	T	F	S	S	WK
	FIRST QUARTER									THIRD QUARTER							
	26	27	28	29	30	31	1	52									
	2	3	4	5	6	7	8	1		3	4	5	6	7	8	9	27
JAN	9	10	11	12	13	14	15	2	JUL	10	11	12	13	14	15	16	28
5	16	17	18	19	20	21	22	3	5	17	18	19	20	21	22	23	29
WKS	23	24	25	26	27	28	29	4	WKS	24	25	26	27	28	29	30	30
	30	31	1	2	3	4	5	5		31	1	2	3	4	5	6	31
FEB	6	7	8	9	10	11	12	6	AUG	7	8	9	10	11	12	13	32
4	13	14	15	16	17	18	19	7	4	14	15	16	17	18	19	20	33
WKS	20	21	22	23	24	25	26	8	WKS	21	22	23	24	25	26	27	34
	27	28	1	2	3	4	5	9		28	29	30	31	1	2	3	35
MAR	6	7	8	9	10	11	12	10	SEP	4	5	6	7	8	9	10	36
4	13	14	15	16	17	18	19	11	4	11	12	13	14	15	16	17	37
WKS	20	21	22	23	24	25	26	12	WKS	18	19	20	21	22	23	24	38
	27	28	29	30	31	1	2	13		25	26	27	28	29	30	1	39
	SECOND QUARTER									FOURTH QUARTER							
	3	4	5	6	7	8	9	14		2	3	4	5	6	7	8	40
APR	10	11	12	13	14	15	16	15	OCT	9	10	11	12	13	14	15	41
5	17	18	19	20	21	22	23	16	5	16	17	18	19	20	21	22	42
WKS	24	25	26	27	28	29	30	17	WKS	23	24	25	26	27	28	29	43
	1	2	3	4	5	6	7	18		30	31	1	2	3	4	5	44
MAY	8	9	10	11	12	13	14	19	NOV	6	7	8	9	10	11	12	45
4	15	16	17	18	19	20	21	20	4	13	14	15	16	17	18	19	46
WKS	22	23	24	25	26	27	28	21	WKS	20	21	22	23	24	25	26	47
	29	30	31	1	2	3	4	22		27	28	29	30	1	2	3	48
JUN	5	6	7	8	9	10	11	23	DEC	4	5	6	7	8	9	10	49
4	12	13	14	15	16	17	18	24	4	11	12	13	14	15	16	17	50
WKS	19	20	21	22	23	24	25	25	WKS	18	19	20	21	22	23	24	51
	26	27	28	29	30	1	2	26		25	26	27	28	29	30	31	52
										1	2	3	4	5	6	7	1
MO	M	T	W	T	F	S	S	WK	MO	M	T	W	T	F	S	S	WK

NDE Training Program 3Cs: Classroom, CBTs, and Certs

Classroom Training

- Nondestructive Evaluation of Concrete
- Visual Examination Levels I, II & III
- Nondestructive Evaluation for Engineers (5-day and 3-day)
- Ultrasonic Examination Levels II & III
- ASME Section XI Flaw Evaluation
- Boric Acid Corrosion Control Limited VT-2
- Advance UT Level II - Through-wall Flaw Sizing
- Ultrasonic Examination of Austenitic Stainless Steel Pipe Welds for Cracking
  - PD Lab Session
- Nondestructive Evaluation Instructor Training
- Level III Basic
- Level III Specific

CBTs

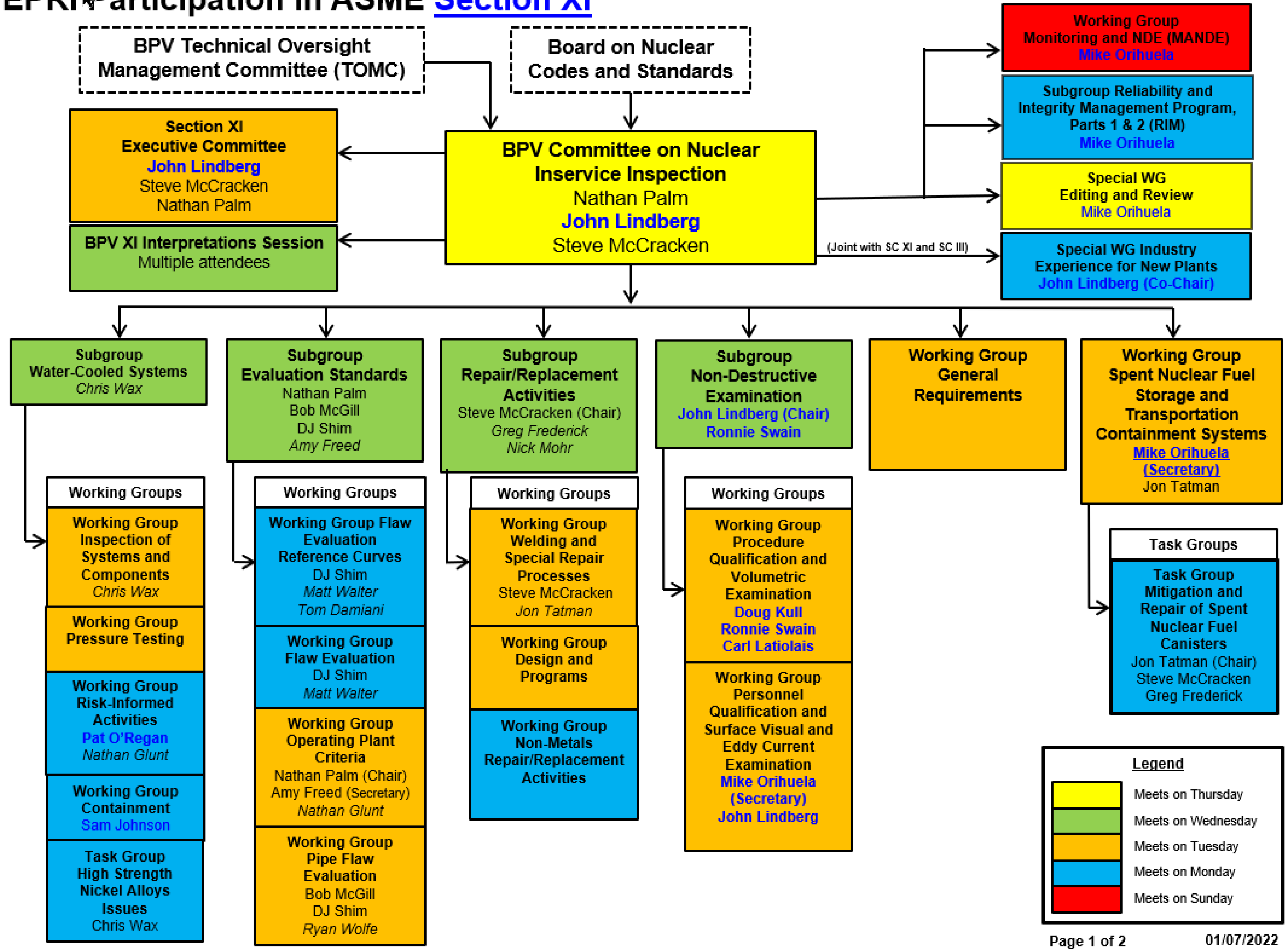
- Flaw Characterization and Evaluation
- 2021 Remote Visual Inspection for Reactor Vessel Internals
- ASME Section XI CBT (923A) Version 1.0 (English and Spanish version)
- Computer-based Training for the Ultrasonic Examination of Austenitic Stainless Steel Pipe Welds for Cracking
- Visual Identification of Aging Degradation - Aging Management
- Fundamentals of Aging Degradation and Management - Aging Management Series
- Metals Aging Degradation Mechanisms - Aging Management
- Concrete Aging Degradation Mechanisms - Aging Management
- Selective Leaching - Aging Management
- 2020 Aging Management Activities for corrosion of concrete reinforcement
- Quality Control Receipt Inspection
- Buried Pipe Condition Assessment and Repair
- Introduction to Phase Array with a Nuclear Focus
- ASME Section XI Flaw Evaluation
- Visual Examination VT-2 System Walkdown (BACC)
- Visual Examination of Concrete Containments (IWL) [Assembled package]

Certifications

- Visual Inspections:
  - Level I
  - Level II
  - Level III
- Ultrasonic Inspections
  - Level I
  - Level II
  - Level III
- Includes classroom and inspection training

EPRI Participation in ASME Section XI

= NDE Staff



EPRI Participation in ASME Section XI Task Groups

= NDE Staff

Working Group Welding and Special Repair Processes
Steve McCracken
Jon Tatman

Task Groups

- **Temper Bead Welding (Meets virtually the week before Code Week)**
  Greg Frederick
  Steve McCracken
  Jon Tatman
- **Repair and Replacement Optimization (Meets virtually the week before Code Week)**
  Steve McCracken (Chair)
- **Weld Overlay (Meets virtually the week before Code Week)**
  Steve McCracken (Chair)

Working Group Procedure Qualification and Volumetric Examination
Doug Kull
Ronnie Swain
Carl Latiolais

Task Groups

- **Cast Stainless Steel**
  Ronnie Swain
  Doug Kull
- **Alternative NDE for RRA**
  Mike Orihuela
- **Appendix VIII**
  Doug Kull (Chair)
  Ronnie Swain
- **Task Team Defining Essential Characteristics of UT Systems**
  Doug Kull (Chair)

Section XI Executive Committee
John Lindberg
Steve McCracken
Nathan Palm

Task Groups

- **Inspectability**
  John Lindberg, Chair
  Carl Latiolais
  Pat O'Regan

Working Group Operating Plant Criteria
Nathan Palm (Chair)
Amy Freed (Secretary)
Nathan Glunt

Task Groups

- **Task Group Appendix L (Meets virtually the week before Code Week)**
  Nathan Glunt (Chair)
  DJ Shim
  Amy Freed

Working Group Pipe Flaw Evaluation
Bob McGill
DJ Shim
Ryan Wolfe

Task Groups

- **Flaw Evaluation in HDPE Pipe**
  DJ Shim
  Ryan Wolfe
- **N-513**
  Bob McGill (Chair)
- **Evaluation Procedures for Degraded Buried Pipe (Meets virtually the week before Code Week)**
  Bob McGill (Chair)

Working Group Non-Metals Repair/Replacement Activities

Task Groups

- **HDPE Piping for LSS Systems**
  Steve McCracken
- **Repair by Carbon Fiber Composites**
  Dylan Cimock

Other Section XI Groups w/o EPRI Participants

SUNDAY:
- WG on MANDE

MONDAY:
- TG HDPE Repair/Replacement

TUESDAY:
- JSME/ASME Joint WG for RIM Processes and System Based Code

WEDNESDAY:
- TG Evaluation of Beyond Design Basis Events

Legend

Yellow	Meets on Thursday
Green	Meets on Wednesday
Orange	Meets on Tuesday
Blue	Meets on Monday
Red	Meets on Sunday

Page 2 of 2 01/07/2022

Together…Shaping the Future of Energy®

WRTC Program Review

ACRS Information Exchange

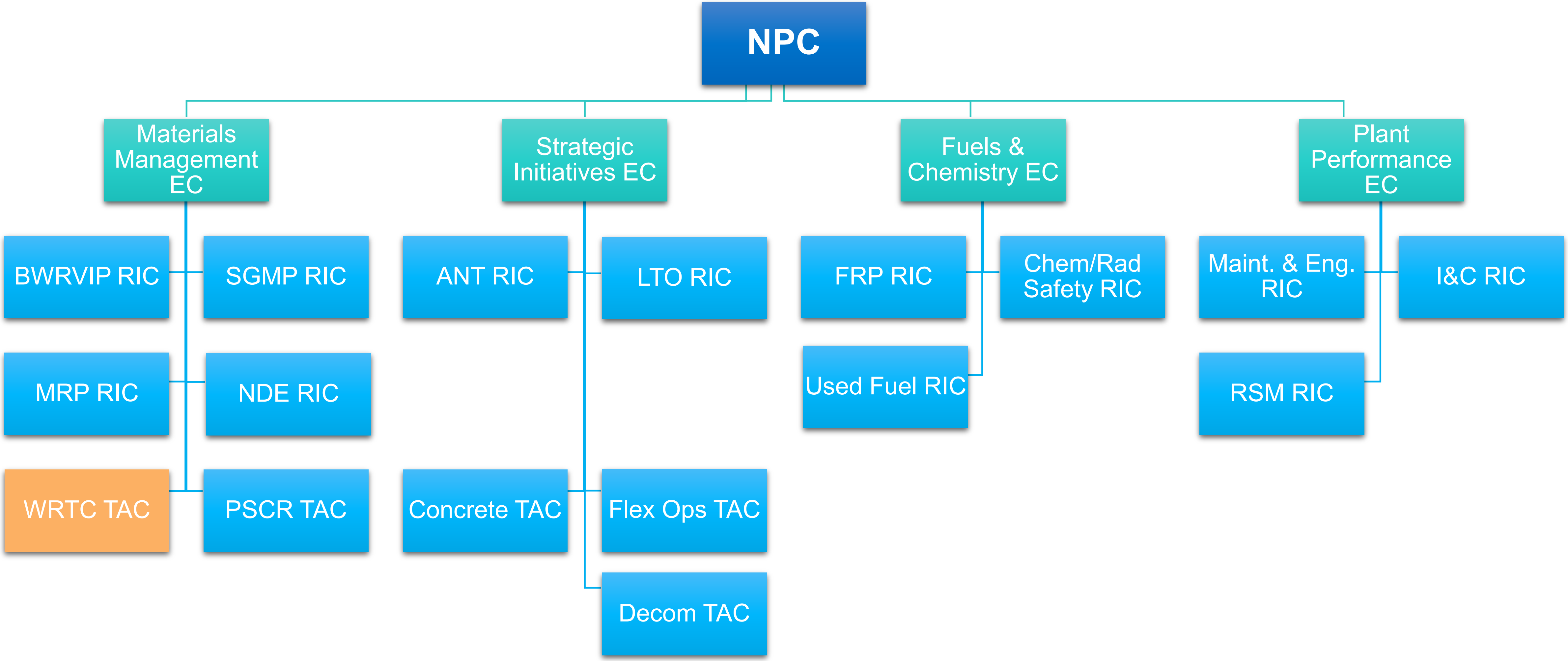
Greg Frederick
EPRI, Program Manager

ACRS Fuels, Materials, and Structures SC Meeting
March 22, 2023

Content

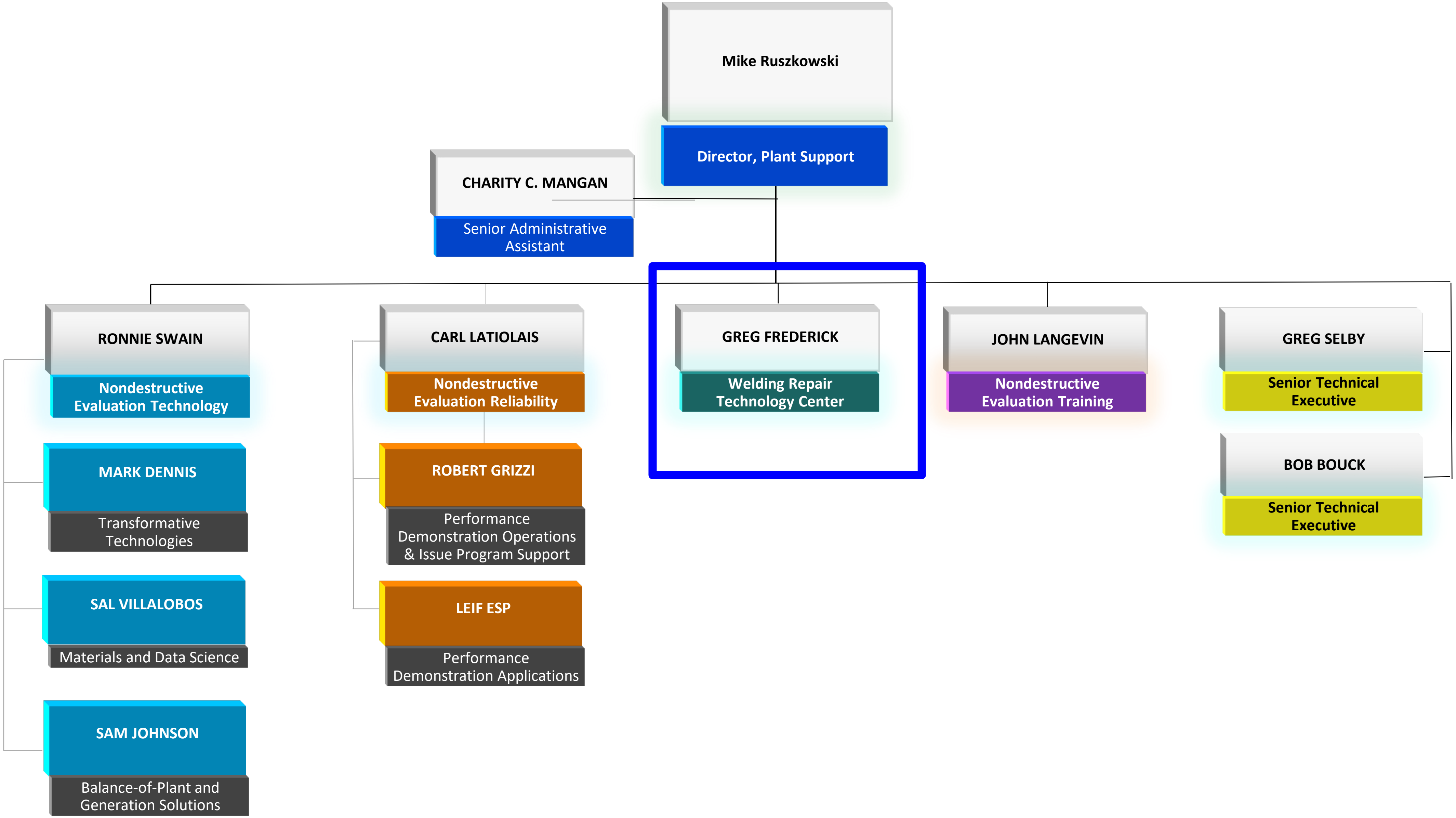
- WRTC Program Advisory Structure
- WRTC Program Organizational Structure
- WRTC Program Members & Participants
- 2023 Research Focus Areas
  - WRTC RFA 6
    - Engagement in ASME Code Committees
    - Annual Report
  - WRTC RFA 7
    - Training Program
  - Other Related engagement

WRTC Program Advisory Structure

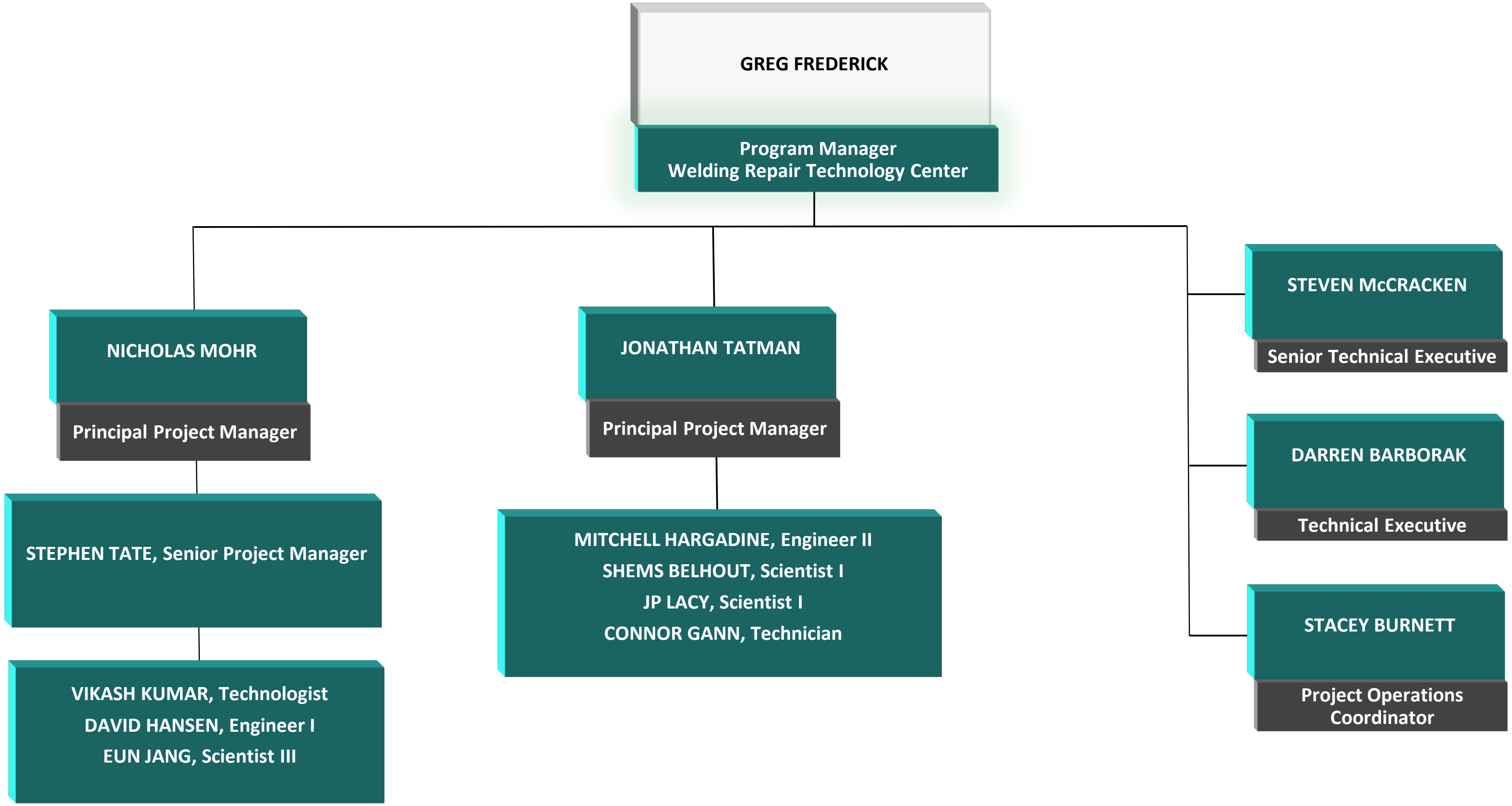


Revised: 3/8/2022

Plant Support Organization Chart



Welding Repair Technology Center Organizational Chart



Current Members

United States (TAC)

- 22 of 22 U.S. Utility Organizations participate in WRTC (all operating BWR and PWRs)

International Participation (TAC)

- CANDU Owners Group (COG) – Canada, Romania
- CEZ A.S. – Czech Republic
- Chubu Electric Power Co., Inc. – Japan
- Chugoku Electric Power Co., Inc. - Japan
- Comision Federal de Electricidad (CFE) - Mexico
- Electricite de France S.A. (EDF/MAI) – France
- Emirates Nuclear Energy Corporation - United Arab Emirates
- Eskom - South Africa
- Horizon Nuclear – United Kingdom
- Kansai Electric Power Co, Inc – Japan
- Kernkraftwerk Leibstadt AG (KKL) - Switzerland
- Korea Hydro and Nuclear Power Co. - Korea
- Kyushu – Japan
- MVM Hungarian Electric (Paks) – Hungary
- Nucleoelectrica Argentina S.A. – Argentina
- Shikoku Electric Power Co – Japan
- State Nuclear Power Technology Company (SNPTC) - China
- The Tokyo Electric Power Company, Incorporated (TEPCO) - Japan
- FORO – Spain
- Vattenfall – Sweden
- OKG - Sweden
- Krško – Slovenia
- China National Nuclear Power (CNNP)
- Rolls Royce Power Engineering - United Kingdom
- TaiPower – Taiwan
- JAPC - Japan

Non-Utility Memberships

◎ IHI Corporation – Japan
- Framatome (AREVA) – Germany, France, US
- Fluor
- KAPL/Bettis – Flour Marine Propulsion Corp.
- Doosan Heavy Industry – Korea
- Westinghouse (024)

◎ *= Resident Researchers in WRTC*

WRTC Objectives

Identify
- Technology gaps related to repair, replacement and fabrication technologies

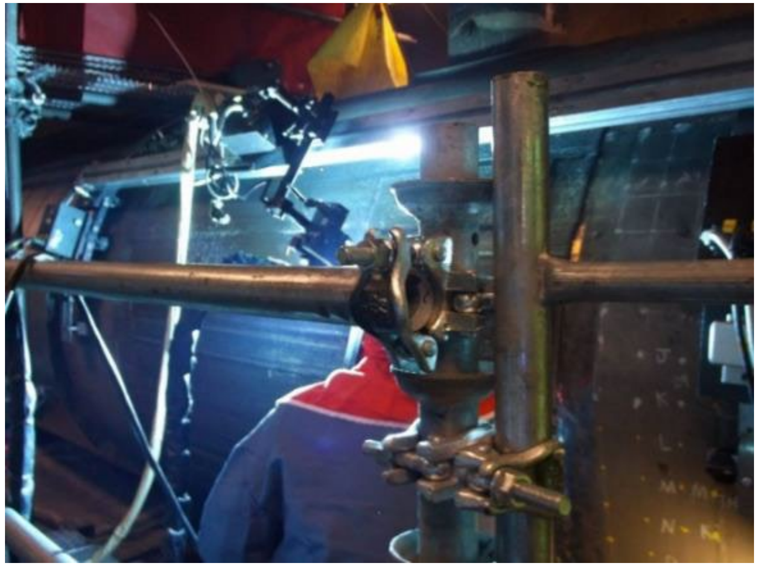
Establish
- Technologies to address gaps in repair and replacement technology for nuclear power generation components
- Field deployable repair options, improved material performance

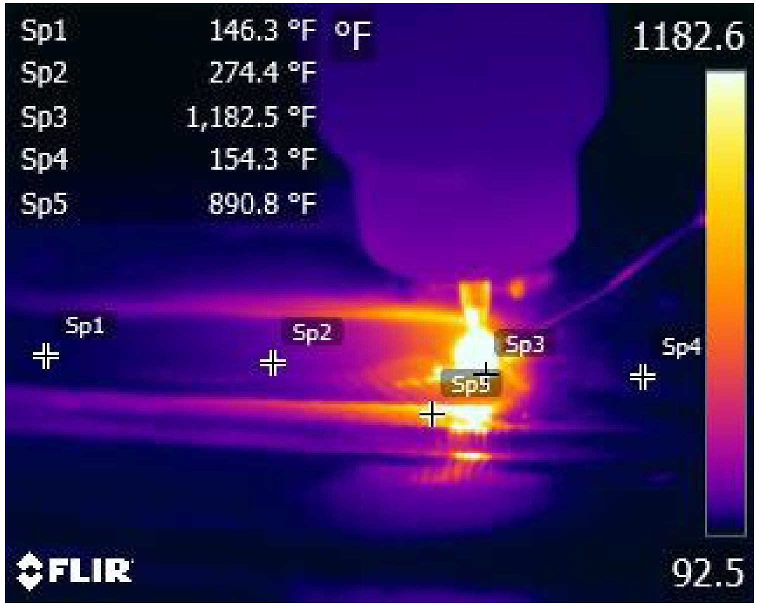
Maintain
- Facilities including metallurgical, welding, material testing and modeling labs with industry experts

Support
- Global collaborations with Research Facilities, National Labs, Universities, and Industry

Transfer
- Supporting technical interactions with Code and Regulations
- Implementation and guidance documents
- Direct assistance, peer interaction and on-site support

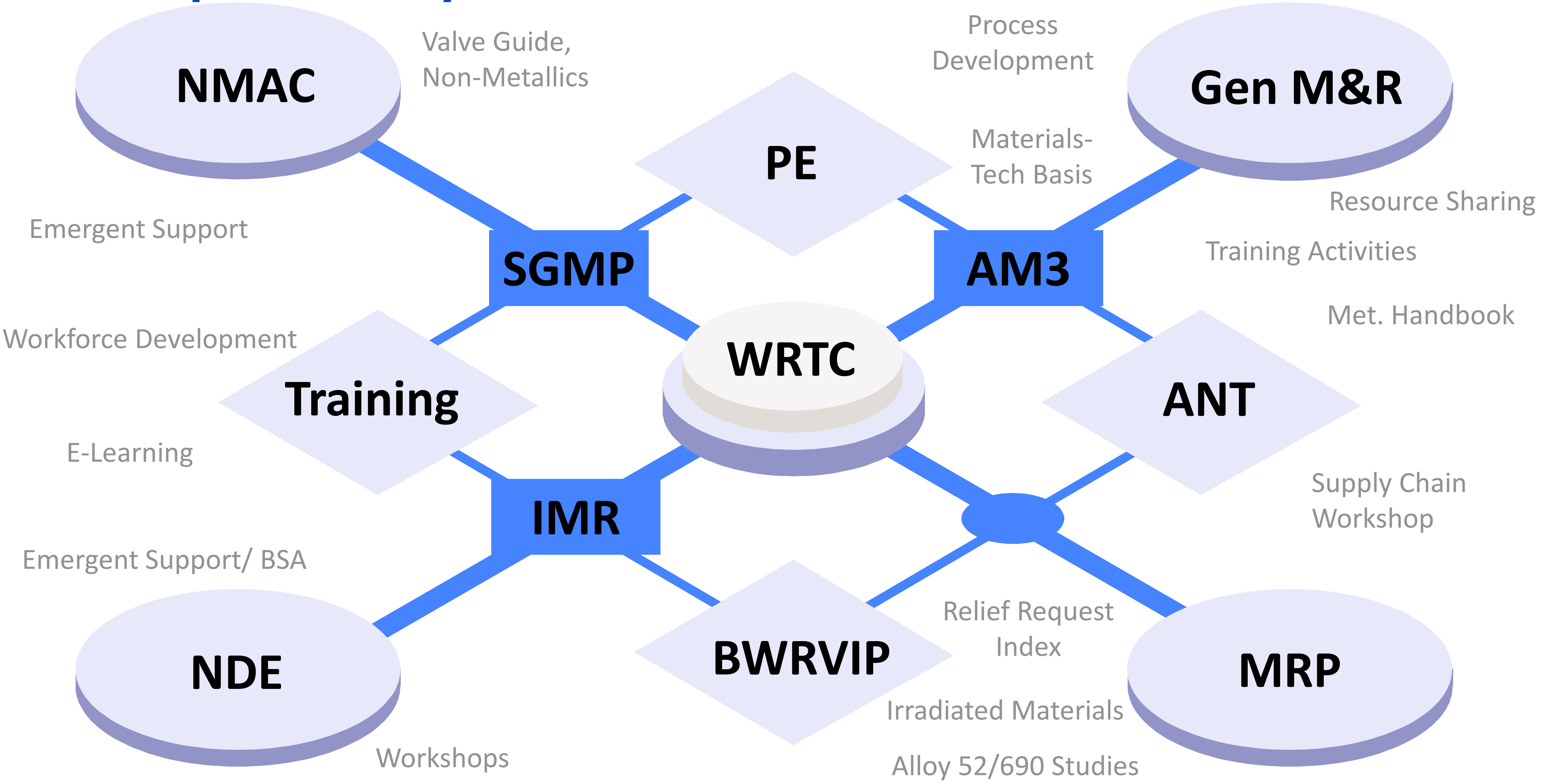
Create
- An interactive process with members with direct engagement with the WRTC staff, welding and materials experts, and industry peers
- Forums for sharing Operating Experience, Information Exchange, Training/Workshops





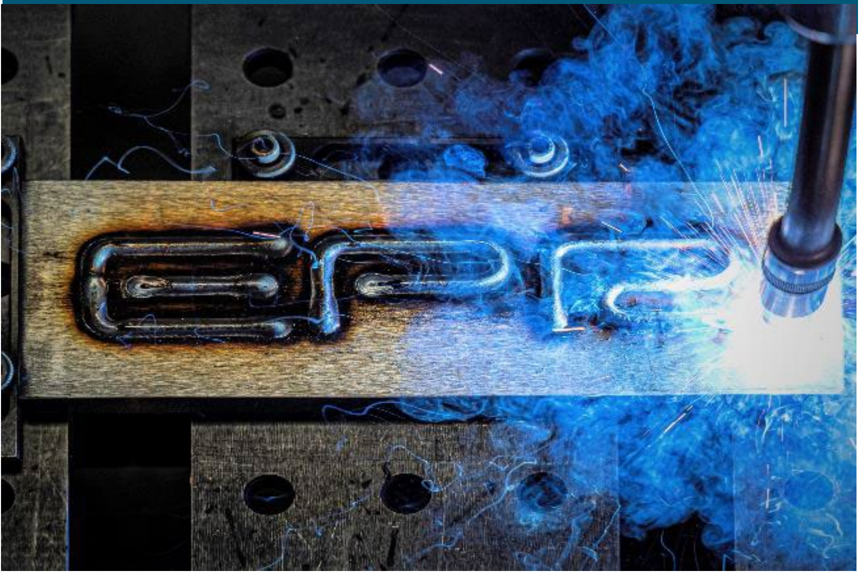
EPRI

Examples of any Cross-Sector Collaboration



WRTC
Research Focus Areas

- **Current Research Focus Areas**
  - **Groups common projects and ideas together**
  - **Mix of Tactical and Strategic (fundamental) Research**

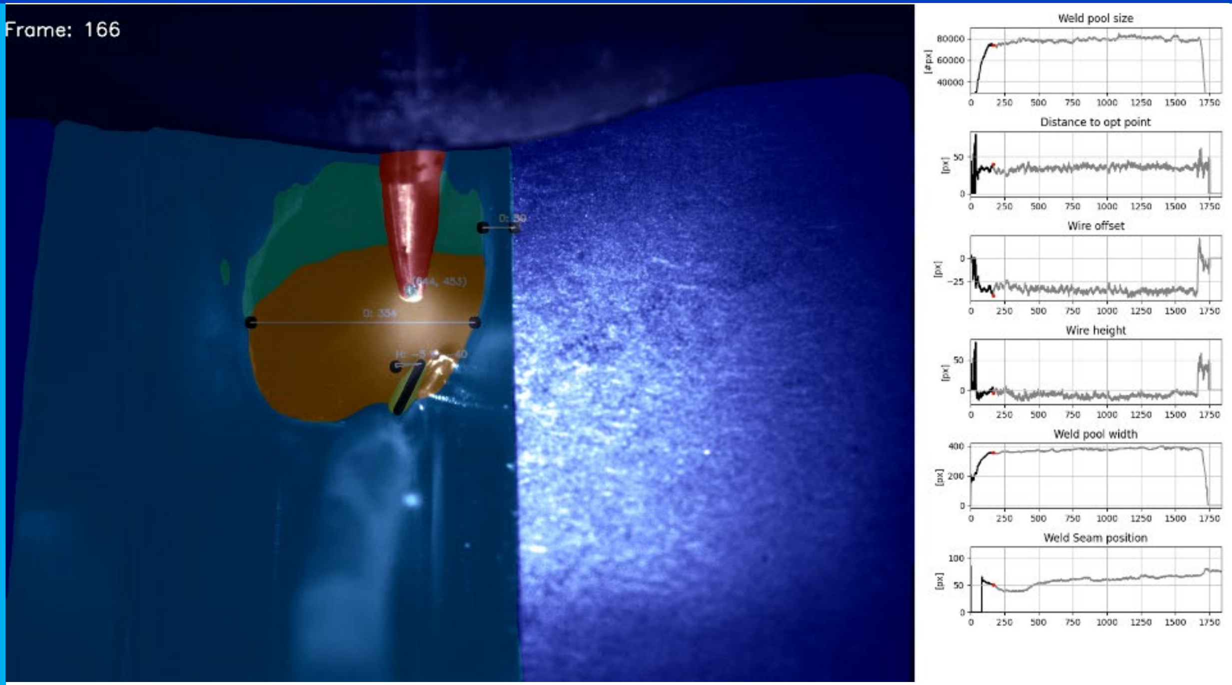


- **RFA 1** Material Weldability and Welding Alloy Development
- **RFA 2** Irradiated Materials Repair Solutions
- **RFA 3** Optimize Joining, Fabrication, and Repair Processes
- **RFA 4** Repair Solutions for Structures
- **RFA 5** Small Bore Piping Issues
- **RFA 6** Codes and Standards
- **RFA 7** Tactical Implementation of Repair Methods
- **RFA 8** Advance Manufacturing - Development and Evaluation

Adaptive Feedback Welding

WRTC: Strategic Project Portfolio

- **Operator-controlled welding is used for most safety-related piping welds in the nuclear industry**
- **Availability of skilled welding operators has become increasingly scarce since the turn of the century**
- **Weld quality/productivity will become a significant issue in the future as the industry struggles to maintain skilled welders**
- **Objective of project is to develop fully-automated welding system that can function as welding operator using real-time sensor data collection and machine learning algorithms**



Value to Nuclear Industry

- ✔ Minimize necessity for post-weld repairs
- ✔ Address future welder workforce supply versus demand
- ✔ Increase safety by removing welding operators from hazardous environments

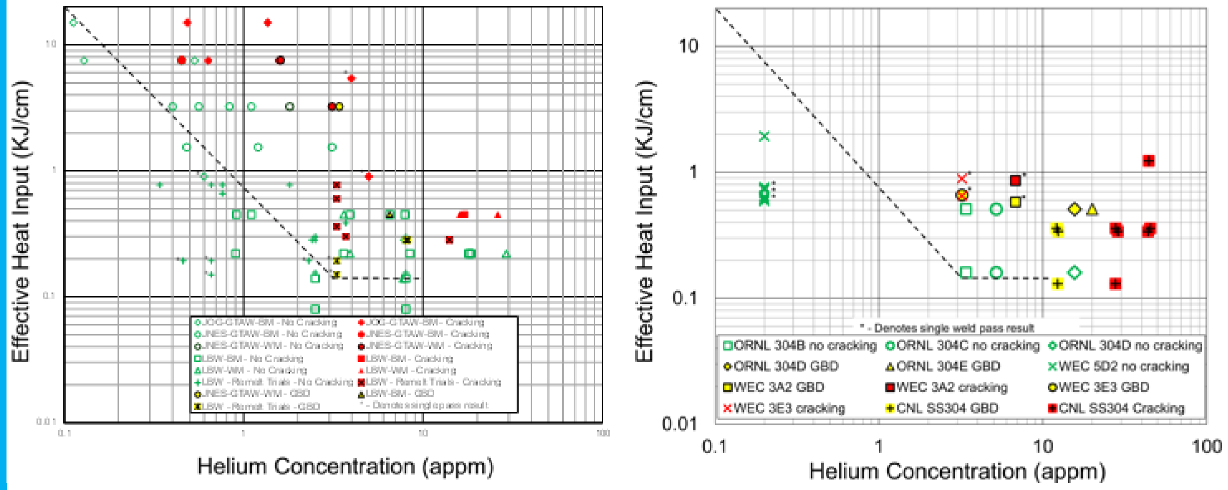
Irradiated Materials Welding

WRTC: Strategic Project Portfolio

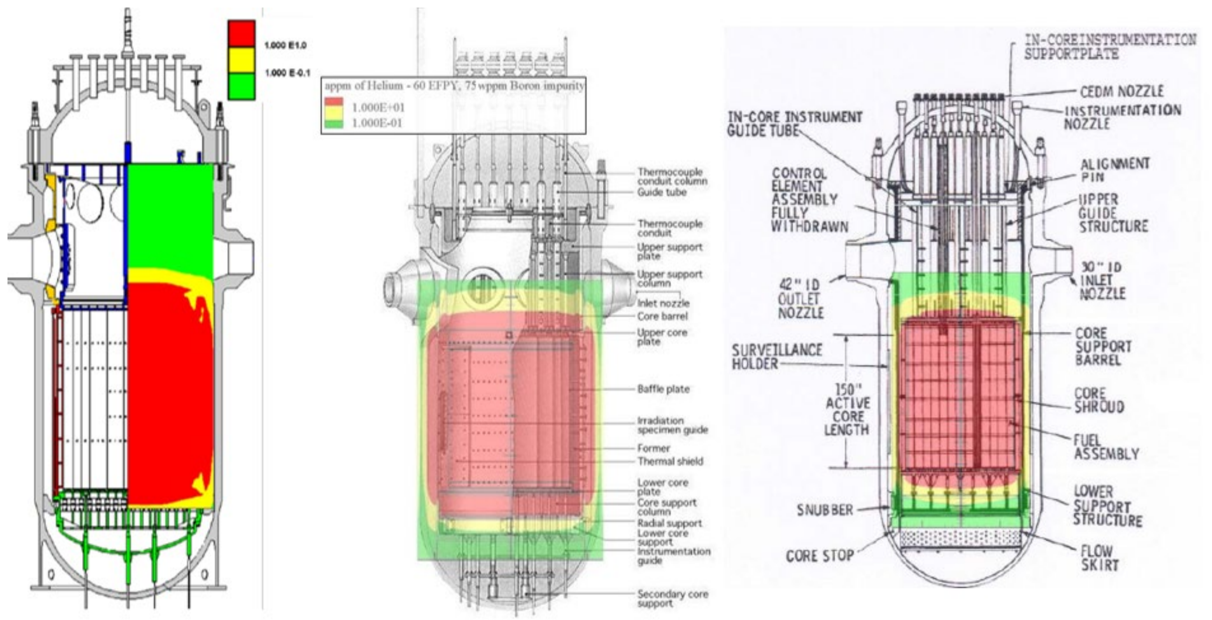
- **Helium generated by neutron transmutation reactions of boron and nickel can result in formation of helium-induced cracks when welded**
- **Comprehensive weld data collection and helium generation maps are required to establish guidance**
- **Renewed member interest based on recent core barrel cracking issue at Robinson**
- **Heightened emphasis on project is needed to adequately support current operating fleet in the event reactor internal weld repair is only solution:**
    - Irradiated material weld data collection
    - Development of field-deployable welding systems for underwater reactor internals
    - ASME code case development

304 Helium Weldability Threshold Plot

Historical Japanese Data | EPRI Data



PWR Helium Generation Maps



B&W Reactor | Westinghouse Reactor | CE Reactor

Temper Bead Research Activities at EPRI

New Effective Heat Input Equation for Temper Bead Welding [1]

Hardness Protocol for Ambient Temperature Temper Bead Procedure Qualification [2]

Modeling for Development and Optimization of Temper Bead Techniques

Future Temper Bead

1. *Welding and Repair Technology Center: Development of Improved Weld Heat Input and Dilution Equations for Consumable Welding Processes.* EPRI, Palo Alto, CA: 2013. 300200412
2. *Welding and Repair Technology Center: Alternative Hardness Test Protocol for Qualification of Temper Bead Welding: Preliminary Report.* EPRI, Palo Alto, CA: 2014. 3002003139.

Task Group - Canister Mitigation and Repair: Status

- Inspection strategies are in place to examine spent fuel canisters
  - ASME Code Case N-860 defines inspection requirements
  - Canister storage sites are already using inspection programs defined prior to completion of N-860
  - Currently visual inspections, potential follow up with surface/volumetric
  - Experience tells us to be prepared to address indications before doing surface or volumetric exams
- ASME Task Group launched July 2021 to define mitigation and repair requirements for spent fuel canisters
- **Oct 2021:** First Code Case under TG will be mitigation by cold spray
- **Feb-Aug 2022:** Cold spray mitigation concepts and Code Case development
  - SMEs from PNNL, SNL, VRC and Westinghouse contributed to definition of essential and non-essential parameters
- **Nov 2022:** Draft cold spray mitigation Code Case presented to TG for discussion, stakeholders
- **Cold Spray CC Next Steps:** Technical Basis document, Approval vote from TG, Presentation and review by SG-RRA and Canister WG
- **TG Canister Mitigation and Repair Next Steps:** Once cold spray CC is stable, TG selects next technique for new CC
  - Possibly by Oct 2023 / Jan 2024 Code Week meeting
  - Possible techniques: Repair welding (laser, friction stir), other mitigation form

EPRI

WRTC is developing implementation guidance and training to support repair and mitigation efforts.

Under WRTCs **RFA: 7** – Tactical Implementation of Repair Methods;

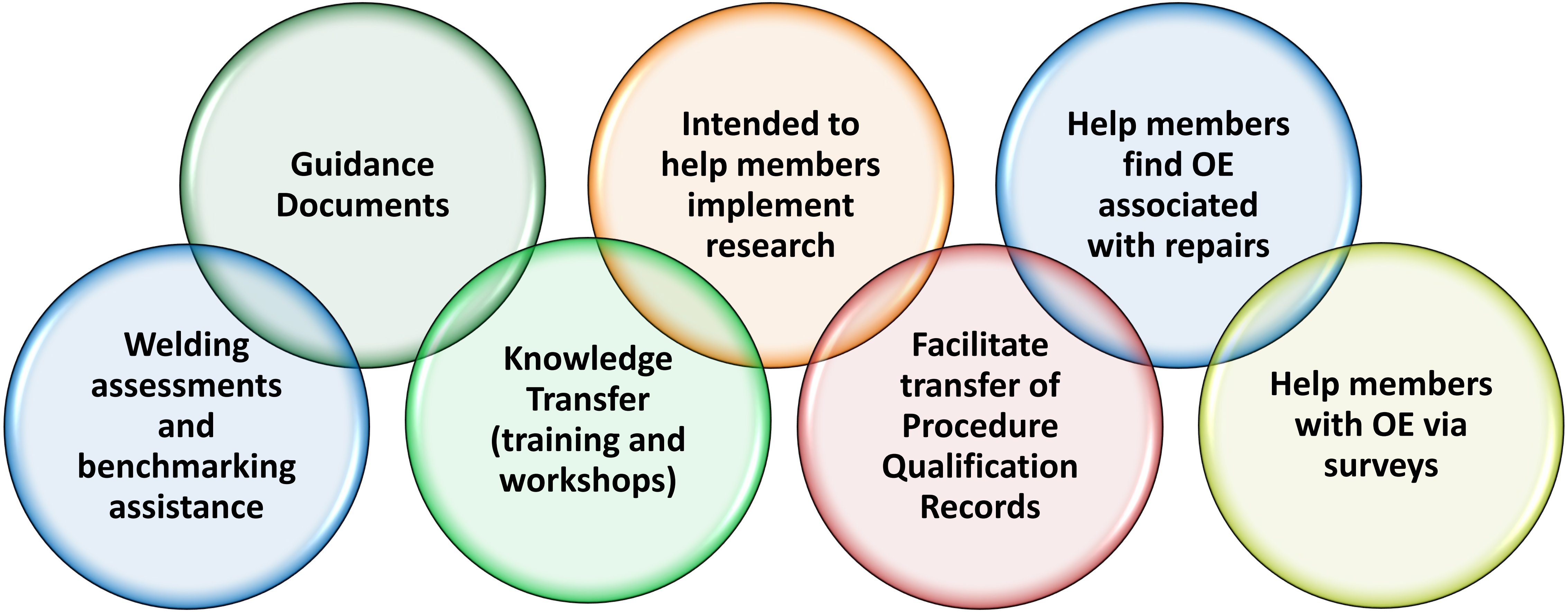
- Technology Transfer
  - Information Exchange
- Developing Guidance documents and training tools
  - Conducting Regional Training and developing Computer Based Training (CBTs)
  - Guidance and Implementation Documents
    - Developing Events Management Response Tool (EMRT)
    - Developing WRTC Wiki
    - Various Guidance documents

WRTC supporting material testing and evaluations for Advance Manufacturing

- Under WRTCs **RFA 8**; Advance Manufacturing - Development and Evaluation
  - Supporting EPRI Advance Manufacturing Initiative (AM3)
  - Support of advance manufacturing methods
    - Powder Metallurgy manufacturing processes.
    - Additive methods of manufacturing
    - Supporting Code Case development for additive materials.

WRTC – Training *Initiative*

Emphasize on - development of guidance documents to facilitate implementation of research, capturing operating experience, transfer of knowledge through research, surveys, workshops, and training.



Training

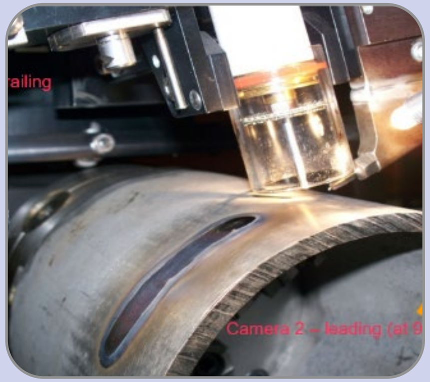
Background:

- WRTC began offering training at WRTC TAC meeting over 12 years ago.
  - Repair and Replacement Training
  - Welding Personnel Introductory Training
  - Construction Code Training
  - Advanced Welding Process Training
  - Hands-on Welding
  - Friction Stir Welding
  - Repair of Buried Piping Training
  - Operational Leakage Workshop
  - Socket Weld Workshop
  - Temper Bead Welding Workshop, etc.
- More recently focusing on Regional training at utility locations
  - Intended to make training available to one or more utilities in close regional proximity

- **Value to Members:**
  - **Maximize value for members attending TAC meetings by providing desired training or workshop topics that deepen understanding or help address industry issues**
  - **Extend knowledge transfer to a broader audience by taking the WRTC TAC training/workshops to member locations**
  - **Obtain additional professional development hours (PDH) that can be used for maintaining certifications and licenses**

Training, Workshops, and Webinars


Welding and Repair Technology Center: Risk-Informed Repair and Replacement Code Case N-752
Implementation Guideline



Risk Informed-Repair and Replacement Webinar *

***WRTC: Risk-Informed Repair and Replacement Code Case N- 752— Implementation Guideline. EPRI, Palo Alto, CA: 2019. 3002015823.**

Rolled Plate Repair Training (N-786, N-780, N-852)

Socket Weld Workshop

Temper Bead Welding Workshop

N-513 Workshop

Overview of Construction Codes

Repair and Replacement Training

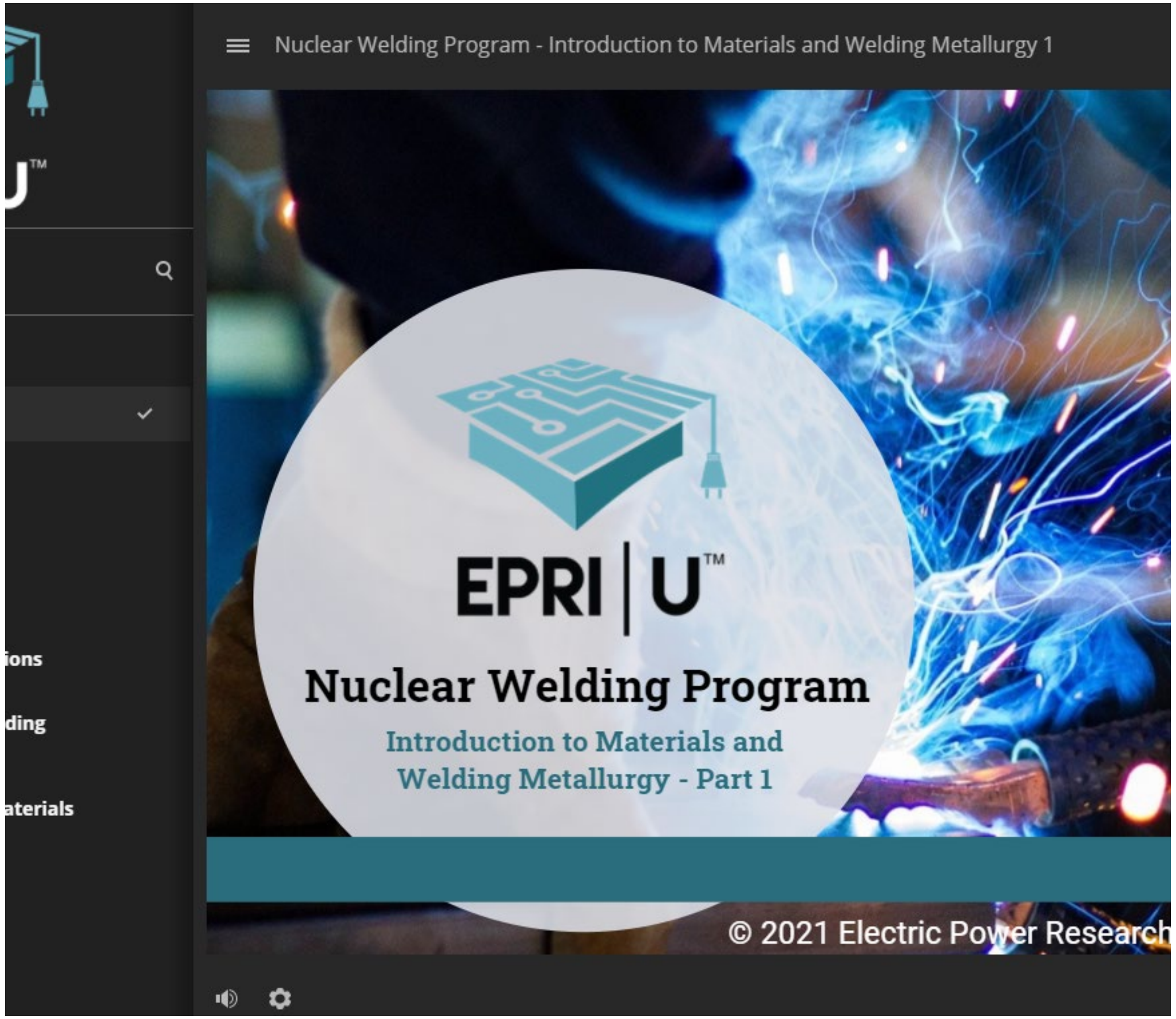
Welding Fundamentals

Practical Application of ASME IX+

+Revision in-process

WRTC offers these and other topics in several formats from webinar to classroom training

Another focus is CBTs – 12 updated in 2022 (Fundamental Modules-EPRI U)



- Nuclear Welding Program Overview
- Introduction to Welding, Brazing, and Fusing
- Introduction to Weld Configurations, Considerations, and Defects
- Introduction to Materials and Welding Metallurgy Part 1
- Introduction to Materials and Welding Metallurgy Part 2
- Introduction to ASME Code
- Introduction to ASME Section IX
- Welding Filler Metal
- Nuclear Welding Program Part 1
- Nuclear Welding Program Part 2
- Alternate Repair Methods
- Inspection Techniques
- Socket Weld Training for Craft Personnel

WRTC has 13 E-Learning Modules Available to Members

WRTC TAC and Demonstrations in Charlotte Labs

EPRI


Together...Shaping the Future of Energy®

Additional Attendance list

- Randy Stark, Director, Nuclear Materials
- Jim Cirilli, Nuclear Materials
- Jean Smith, EPRI International Materials Research (IMR)
- Robert (Bob) Grizzi, EPRI NDE
- Kyle Amberge, EPRI Materials Reliability Program (MRP)
- Bob McGill, EPRI MRP
- Nathan Palm, EPRI BWRVIP
- Greg Frederick, EPRI WRTC
- Helen Cothron, EPRI SGMP