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NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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METALLURGY AND REACTOR FUELS SUBCOMMITTEE

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THURSDAY

AUGUST 21, 2014

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ROCKVILLE, MARYLAND

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The Subcommittee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B1, 11545 Rockville Pike, at 8:30 a.m., Ronald G. Ballinger, Chairman, presiding.

COMMITTEE MEMBERS:

RONALD G. BALLINGER, Subcommittee Chairman

JOY REMPE, Member

PETER C. RICCARDELLA, Member

STEPHEN P. SCHULTZ, Member

GORDON R. SKILLMAN, Member

JOHN W. STETKAR, Member

ACRS CONSULTANT:

WILLIAM SHACK

DESIGNATED FEDERAL OFFICIAL:

KATHY D. WEAVER

ALSO PRESENT:

HATICE AKKURT, EPRI

STEFAN ANTON, Holtec International

DON CARLSON, NRO

WILLIAM CARTER, Exelon

KRIS CUMMINGS, NEI

MARIELY DIAZ COLON, NRR

ROBERT EINZIGER, NMSS

MATT EYRE, Curtiss Wright

JILL FISHER, Exelon

MIRELA GAVRILAS, RES

MATTHEW HISER, RES

ROBERT JONES, Southern Nuclear*

KEVIN KOSKI, FirstEnergy

SCOTT KREPEL, NRR

GLORIA KULESA, NRR

DALE LANCASTER, NuclearConsultants*

DOUG MABEY, Southern Nuclear*

GREG MAKAR, NRO

TIM MCGINTY, NRR
ED MERCIER, Westinghouse
AMRIT PATEL, NRR
APRIL PULVIRENTI, RES
GLEN SEEBURGER, AREVA, Inc.
UNDINE SHOOP, NRR
MAKUTESWARA SRINIVASAN, RES
SPYROS TRAIFOROS, NRR
ROB TREGONING, RES
MIKE VELAZQUEZ, NMSS
EMMA WONG, NMSS
KENT WOOD, NRR
MATTHEW YODER, NRR

*Present via telephone

A G E N D A

P R O C E E D I N G S

8:29 a.m.

CHAIRMAN BALLINGER: Okay. The meeting will come to order, please. This is a meeting of the Metallurgy and Reactor Fuel Subcommittee. I'm trying to be deliberately slow because we have an interface with signing going on.

I'm Ron Ballinger, Chairman of the Subcommittee. ACRS Members in attendance are John Stetkar, Pete Riccardella, Steve Schultz, Gordon Skillman and Joy Rempe. Our consultant, Bill Shack, is also present. Kathy Weaver of the ACRS Staff is the Designated Federal Official for this meeting.

The purpose of this meeting is to receive a briefing from Staff on neutron absorber degradation and the Generic Letter, proposed Generic Letter. Also, we will hear about the industry's perspectives on spent fuel pool criticality evaluations, issues and recent developments from NEI.

The Subcommittee will gather information and analyze relevant issues and facts, and formulate proposed position and action, as appropriate, for deliberation by the Full Committee meeting which will be September 4th, this year.

The rules for participation in today's

meeting have been announced as part of the notice of this meeting previously published in the Federal Register on July the 23rd, 2014.

A transcript of this meeting is being kept and will be made available as stated in the Federal Register Notice. It is requested that speakers first identify themselves and speak with sufficient clarity, this is very important here especially, and volume so that they can be readily heard. Also, shutdown all the iPhones, androids, and other things that go buzz, ring, chime, whatever.

We have not received any requests from members of the public to make oral statements or written comments. We have a bridge line set up which will be put in listen mode only, but will be opened for comments toward the end of the briefing.

We will now proceed with the meeting, and I call upon Tim McGinty, Division Director, NRR, Division of Safety Systems to give a brief introduction and introduce the presenters. It's your's.

MR. McGINTY: Thank you very much. I'm Tim McGinty, the Division Director of Safety Systems in NRR. I want to thank the members of the Subcommittee for taking the time today to hear the Staff's, as well as industry's presentation on the degradation of

neutron absorbing materials and spent fuel pools Generic Letter.

The degradation of neutron absorbing materials has been an issue since the 1980s, as with essentially the discovery of the degradation with Boraflex. Recent events have raised concerns for the Staff regarding the adequacy of the methodologies and the service B- and the surveillance programs for some licensees with respect to degradation.

This is not an immediate safety concern; however, I do want to highlight that it is a safety concern. It is a reduction in the subcriticality margin available in the spent fuel pools, and as such the Staff is proposing this Generic Letter to address this ongoing concern.

The Generic Letter that we've proposed asks licensees for information regarding monitoring programs and their surveillance programs, and the underlying basis thereof. It doesn't request any new analysis, any new programs, or any research on the parts of licensees.

Just on Tuesday I received a letter from NEI, Kris Cummings, who you'll be hearing from later today, proposing an industry initiative to establish neutron monitoring programs across the industry. And

we haven't had the chance to fully assess that yet, but I'm sure you'll be hearing much more about it during the conduct of today's meeting, as well as we'll be learning, too. And we're interested in working with industry to better understand that. With that, I'll turn it over to our Staff for the rest of the presentation.

MEMBER REMPE: Before you go on, though, on Slide 3 it talks about in several cases "the absorbing materials were found to be outside the bounds established by the assumptions of the analysis of record." How many cases, and were they for Boraflex, Boral, carborundum?

MR. WOOD: I don't know we have an exact number of cases that we've kept track of. There are C-- and primarily these have been Boraflex and carborundum to date. The question is, you know, if there are concerns with some of these other materials, if you don't have a monitoring program now to establish baseline you won't know when degradation starts or what degradation rates are when they start occurring.

MEMBER REMPE: I'd like a little more detail because I actually read all the material and I'd like some specifics, if you don't mind, how far they were out. And, again, more details because B- before the

full Committee if possible, please.

MR. WOOD: I can get those. I have some backup slides that I'll bring after B- I'll get on the break and bring up. We can talk about that this afternoon or later this morning.

MEMBER REMPE: Great, thank you.

MR. WOOD: Okay. My name is Kent Wood. I'm the Team Leader for the Spent Fuel Team in the Reactor Systems Branch in the Division of Safety Systems in the Office of Reactor Regulation. I've got several people that work on the team with me, and Scott Krepel is one of them. He's the lead for getting the Generic Letter done, for getting that. Also, we have here with us on the table in front right now is April Pulvirenti. She's a research doctor, chemist in Office of Research. She's been doing work with neutron absorbing materials, research in that regard. And then Matt Yoder. He's a chemical engineer in the Division of Engineering in NRR, as well. We'll hear from them later on.

This is just an overview. What I'm going to put up is an introduction, some background. Talk a little bit about the neutron absorbers, introduce those. There'll be a lot more details going on and coming later. Talk a little bit about reactivity designs, I'm sorry, rack designs, and then reactivity

effects.

The requirements are B- the requirements can be found in several regulations. There is 10 CFR 70.24, which was the original requirement which basically requires you to monitor, detect, mitigate, and recover from an inadvertent criticality event and the storage of fuel. It requires emergency plans and drills, and whatnot.

When plants were first licensed, the reactivity of the spent B- for the fuel was living on relatively even lower enrichments. You're talking 3 percent, the pitch on the racks was 10-inch pitch or more, you had large flux traps, and you can control reactivity very easily through geometry. You didn't need neutron absorbers, and they were low density racks.

There is also a general design criteria 62. It specifically talks about prevention of criticality, the storage. There's GDC 61 which basically talks about everything else in fuel storage.

In 1998, the NRC B- most people were getting exemptions to the 70.24 rule because it was easy to demonstrate subcriticality, and the NRC was granting exemptions for the fuel storage for the new licensees because of their analysis that shows that even though

the fresh fuel couldn't go critical, all on burned fuel.

As the pool started to fill up and the fuel wasn't being shipped off site, they needed more capacity, started re-racking, the pools started becoming higher density. To do that, they started re-racking on narrow pitch, and they needed a poison to do that. They were still regulated by exemptions to 70.24. They would change their analysis to show they would meet the subcriticality requirement.

In '98, the NRC said we are going to stop regulating by exemptions to 70.24, and they wrote 10 CFR 50.68. 10 CFR 50.68 has paragraph 4, which talks about the pool storage which says B- it's got a couple of different requirements in there. One is if you don't credit soluble boron, this certainly applies to all the boiling water reactor spent fuel pools because they don't have it, then you have to have your k effective less than or equal to .95 with 95 percent probability, with 95 percent confidence.

If you do credit soluble boron, which is an option for the PWRs, which most of them have exercised, then you have to meet two requirements simultaneously. One is you have to demonstrate by analysis that your pool is less than 1 without any consideration of soluble boron and it is present. And

the other one is that you have to be less than or equal to .95 with consideration for the soluble boron that is present. These are both in the 95 percent probability, 95 percent confidence factor. That's part of the regulation.

The k effective less than 1 without soluble boron was to limit how much soluble boron could be accounted for and bound in design-basis accidents. The other one that applies, of course, is 10 CFR 50.36, like it applies to any other safety-related components in the plant.

MEMBER SKILLMAN: Kent, let me ask this question, please. I'm Dick Skillman.

MR. WOOD: Yes, sir.

MEMBER SKILLMAN: Your comment, your opening comment pointed to the need for this letter based on the recognition that margin might be being depleted for a number of issues, but you also said that for years the NRC governed with exceptions to 70.24. And I think what you were communicating is there was so much margin in the old pools because of geometry, there really wasn't a safety concern.

MR. WOOD: Well, it's B- that was the initial instruction for them. You know, it would be very easy to do a very conservative, very simplistic type

of analysis based on the pitch and the aerial density to say, you know, what's the k effect of this pool? It's very low. We now B- we're having high density B- you know, we have high density storage racks where essentially the pitch is almost identical to what B- like almost what it is in the core. You're having the neutron absorbers have to be credited for. You are now having other things that are driving B- and I'll get to this in a minute here.

MEMBER SKILLMAN: Yes, but let me finish my question.

MR. WOOD: Okay.

MEMBER SKILLMAN: My real question was in governing by exemption to 70.24, were you also permitting there to be no monitoring of the poison? In other words, was the k effective so low that in the exemptions that you were granting you were not requiring the licensees to have programs in place to survey the absorption capability of the poison?

MR. WOOD: The NRC, the initial licensees didn't have poisons. Then they started adding poisons as they came to higher densities. And it's my understanding that some of those B- most of those weren't required to have monitoring programs. That's part of why we think that, you know, we want to change

B- you know, going forward we believe there needs to be monitoring programs. And part of the reason why we believe there need to be monitoring programs is our historical performance of these ideas.

When they first put the Boraflex in, which is one of the first materials, it was like well, you know, like it's not going to degrade, we're fine. You know, no need to worry about it. And then they started the B- what was revealing was the high levels of silica that was showing up in the spent fuel pools, which then can be transmitted into the reactor RCS during refueling outages, so they started looking for that. That's when they started finding out that there was degrading neutron absorbers.

And then, you know, we issued B- you know, there are several communications that were coming out in the '80s, in the early '90s about the Boraflex degradation, and we issued a Generic Letter 96-04 directing people to come up with a monitoring program for Boraflex. What we didn't do at that time was tell B- have everybody develop a monitoring program for all neutron absorbers. In hindsight, we probably should have.

MEMBER SKILLMAN: Okay.

MR. WOOD: So, we're trying to get smarter

as we go forward and learn, and get better.

MEMBER SKILLMAN: Thank you.

MR. WOOD: Yes, sir. That's some of what my next slide is, the background. If you know high density B- high capacity spent fuel pool storage designs, you know, they start packing them. You know, nobody built another spent fuel pool but they B- we have licensees that were originally licensed for 600 fuel assemblies, now licensed for 3,300 fuel assemblies, and that's all in the same spent fuel pool. And they did that by packing in tighter. They did that by crediting neutron absorbers. Neutron absorbers, particularly Boraflex, is the poster child for the degradation, certainly. That started complicating the analysis.

So, the fuel assemblies are more reactive, not just the enrichment, but there are other things that go into that, too. When you start taking burnup credit, then it's the depletion parameters in the core that can affect your plutonium production. So, for what B- you know, you're tracking U-235 burnup, but you're producing more plutonium, then your fuel assemblies will be more reactive than you thought in the past. And that gets into increased use of burnable poisons and things like that start driving that up as they harden the neutron spectrum in the core.

So we B- then, you know, this has driven the spent fuel pool criticality analysis to be more complex, and the control has to be more complex. We have licensees out there that have 22 pages worth of design features tech specs of how to control their storage requirements in their spent fuel pool, you know, with multiple classifications of the fuel assemblies based on burnup and enrichment, how much burnup, how much enrichment, multiple B- you know, like in B- factored into whether they're going to be stored in a checkerboard with empty cells, cells filled with different burnup requirements, so it can be quite complex.

Neutron absorbing materials, this is basically the material is a naturally occurring B-10 and B4C which we're all familiar with. And it's B- the B4C is captured in some other material. The other material is the silicone rubber, phenolic resin, aluminum, or stainless steel are the ones that are used in the States now. We talk about that a bit more. But their sole function really is to hold the stuff in place, to keep it between the fuel cells. Because B4C, if it is non-soluble, you know, if the material breaks that's holding it in place breaks down, it will fall to the bottom of the pool and with Boraflex you can

actually see piles of the stuff on the bottom of the pool underneath the panels.

These are some of the materials. We have a picture of Boraflex, picture of carborundum, picture of Boral and a metal matrix composite which are the new materials that are being used. Kris Cummings has a bunch of samples that we'll pass around. We thank Kris for bringing those, and I think he might B- do you have a couple of words to say on these things?

MR. CUMMINGS: Yes.

MR. WOOD: We're going to get into this in more detail but we'll go ahead and do that now.

MR. CUMMINGS: That's fine, we can. I can hand out the samples, and I have a few words about them. I'm sorry, I'll identify myself. Kris Cummings, NEI.

I want to thank NETCO and Holtec for providing the samples that you're going to see today. I have samples of Boraflex, the pristine Boraflex, obviously, as manufactured. I also have samples of Metamic, Boralcan, and Boral. And I believe we have some samples, too, of other materials.

MR. YODER: We have several samples. Matt Yoder, NRR. We have several samples, but they're redundant to your's, so I think if you don't mind we'll pass Kris' samples around now.

MR. CUMMINGS: Okay, that's fine. So, the first material is Boraflex, which is obviously the one of concern that we've been talking about. You can see it's a very flexible material. It's trapped in the silicon matrix. I can pass those around for you. Gordon.

The next is Boral. The thing to note with this small piece is that you can see the B4C aluminum matrix tract between the aluminum sheathing or cladding as we call it. If you look real close you can see a very thin aluminum edge on the top and bottom of the material. I just have one sample of that, so I'll pass that around.

Boralcan, that's a full metal matrix material fully dense. If you compare that to the Boral you can see that there is no aluminum cladding, so this is the typical thickness of the metal matrix or really any of them, whether it's Boral, or Metamic or Boralcan, you can see that thickness of material.

And then I have several samples of Metamic which is also a metal matrix material from Holtec. You can take a look at that. That's very, I want to say, similar to Boralcan.

PARTICIPANT: They're all the same?

MR. CUMMINGS: These three are all Metamic, are all the same. That's correct.

PARTICIPANT: The rest is B-

MR. CUMMINGS: Okay, that's fine.

PARTICIPANT: Confuse the teams.

MR. CUMMINGS: And then I did want to mention there's Metamic HT which is a slightly different version. It's not used in spent fuel racks but Holtec brought it, and I thought I'd bring it just for educational purposes.

CONSULTANT SHACK: What is it used for?

MR. CUMMINGS: It's used for spent fuel storage baskets in dry storage casks, so it does serve a similar purpose, criticality control in dry storage and transport casks.

CONSULTANT SHACK: Thank you.

MR. CUMMINGS: You're welcome. And please, if I could get those back. I had to sign my life away to get those.

MEMBER STETKAR: At nuclear power plant cost that's about $12 million worth of material right there. Right?

MR. CUMMINGS: It's probably not that much, but B-

MR. WOOD: What we have with these materials, and we'll get into more details about the degradation mechanisms here, and we could spend days

talking about each one. We'll try and give an overview of some of these. You know, the Boraflex is silicone rubber-based. It breaks down into the gamma field, starts breaking B- starts changing under the gamma field.

The carborundum, which we didn't have an example of, that's B- look at your computer cases. It's like resin or hard plastic, probably not exactly what you've got today. It probably would be more typical to what you would have seen, you know, 20 or 30 years ago, the type of plastic then.

The Boraflex, like I said, it's kind of like an Oreo cookie with the neutron absorbing which is the good part, everybody knows that the center of the Oreo cookie on the inside with the outside B- but it has blisters form on it which raises the laminates, the cladding, forms a gas bubble.

MR. WOOD: Kent, go back and just correct the record. I believe you've misspoke there. You're talking about Boral. I believe you said Boraflex.

MR. WOOD: Oh, I'm sorry. I thought I changed over to Boraflex, to Boral. Sorry. The Boral is the sandwich type of thing, the Oreo cookie type thing. It has blisters on it. The position has been in the past that these blisters have been relatively

small, and cosmetic. We have seen some instances that these blisters continue to grow, and our concern is how big can they get, and what will they cover?

The metal matrix composites that have been passed around, Boral and Metamic, Rio tinto, others, there are fairly similar materials certainly in function. They're fairly new in service. We don't have a lot of service experience with them, so we want to make sure that we get the ground floor set correctly for those materials going forward.

MEMBER SKILLMAN: Kent, let me ask this question. What controls are in place to insure that a licensee when receiving either the new closely spaced racks or inserts that might be used in the racks actually is receiving material whose aerial density is what the calculation intends for that density to be in order to assure neutron absorption?

MR. WOOD: Well, these are safety-related components just like any other safety-related components would be in the plant. They would have to be purchased and inspected under the licensee's Appendix B program.

MEMBER SKILLMAN: Okay. Does the NRC look at that?

MR. WOOD: You know, I mean that's verify

what, the inspections or the vendors? Not to my knowledge that we've ever looked at inspections at the vendors' plants.

MEMBER SKILLMAN: Okay, thank you.

MR. WOOD: Just a few words about rack designs. There are two basic rack designs. One is a high density which is common for BWR and PWR Region 2. This is typical terminology, not necessarily B- not universal terminology. Typical aerial density for that one especially is about 0.22 grams B-10 per centimeter squared.

What this is, if you see here in the middle, it's a box. They make a metal box, and then they put an absorber plate on the outside, and then they cover it with a wrapper plate. It's kind of hard to see here. I'll have a better picture of this later, and another wrapper plate on the outside. And then they start attaching these things at the corner, and then as they attach them at the corner you start enclosing other storage spaces. This is sometimes referred to as the egg crate design. This is what we call our high density racks. There is one sheet of poison between this, for a PWR there's usually a certain amount of burnup credit that's used to store fuel assemblies in this. The BWR design has traditionally not been done at a peak

reactivity so you do an analysis to determine what the peak reactivity of your fuel is over its entire life. And that's what you assume all your fuel assemblies are, and so far that's been good for them for this high density rack.

Another density rack is used for PWRs to store fresh or lightly burned fuel assemblies. Basically, you take the same boxes that you have in the high density racks but you put them on a grid so that between each fuel assembly you actually have two pieces of poison, and it's more flux trap. And with the analysis they've been able to show that that meets the requirements for the fresh fuel assemblies.

CHAIRMAN BALLINGER: I've read this but can you tell me again what Region 2 means?

MR. WOOD: Region 2 is B- you know, it kind of goes back to when they were B- some people have multiple regions now so it's not necessarily a universal language. Region 1 when they were first putting in the high density racks was you would have a Region 1, which would be the moderate density, what I call moderate density because it was still lower density than B- higher density than what was originally there.

CHAIRMAN BALLINGER: Density meaning?

MR. WOOD: Capacity, you know, like you're packing them tighter, you know, packing the fuel assemblies in tighter. So, you know, they wanted a place where they could store fresh fuel or lightly burned fuel if they had to shutdown mid-cycle, so they created a Region 1. And that was the boxes on the grid spacing so you had two pieces of poison and the flux trap between them.

But to get the maximum storage capacity you packed them in as tight as you could, and that was the region B- it was called Region 2. And what they originally put in with the neutron absorber in its pristine condition it was kind of B- you would have one loading curve for the burnup that said, you know, as long as a fuel assembly with enrichment of, you know, X has Y amount of burnup, it can be stored there. You'd be okay. Otherwise, it would have to be shifted off to Region 1. So, that's how they were originally started. It got a little more complex as the Boraflex started to degrade and people had to start getting more creative with the storage configurations, particularly in Region 2, but sometimes also in Region 1, as well, as that material degraded.

CHAIRMAN BALLINGER: Thank you.

MR. WOOD: Sure. One of the new things they

are doing rather than a re-rack today is an insert that was mentioned, and here what we have is you see the little grain aspect here. This actually is the NETCO snap insert. This is representing that more than some of the others. There are other different types of inserts that can go in. There's ones that can go into the guide tubes for PWRs and whatnot.

But the concept here is that you're putting the insert into the storage cell with the fuel assembly. And rather than re-racking and taking out the entire rack and putting it in, you're putting a piece of material in the storage cell with the fuel assembly. By necessity, have to be a little bit thinner than the panels would be otherwise. The wrapper plates and everything are already still there, so they've taken up that space, so you don't have that, so by necessity they have to be a little bit thinner. You know, this gets into an analysis, how much burnup credit you need. You need a little bit more burnup credit than you had before, but usually you maybe need more storage configurations, more checkerboarding patterns, whatnot. Usually, you know, you can always get to some amount of compliance.

The regulatory compliance is established in the analysis of record with the initial B- usually

with the initial B-10 aerial density. And then degradation from that is either accounted for in the initial analysis of record, but usually not. It historically hasn't been.

CONSULTANT SHACK: Does everybody mix these regions up with the checkerboarding that they do, too?

MR. WOOD: I mean, yes. I mean, you'll have different storage configurations, you know, like a 2X2 storage configuration where you'll have fresh B- you know, you'll have fuel assemblies checkerboarded with empty cells. That would be one storage configuration. Another storage configuration would be you have three out of four in a different 2X2 array.

CONSULTANT SHACK: And that would occur B-

MR. WOOD: They could be right next to each other, and it can change back and forth as they move across the pool. Some licensees control it that this specific module does this pattern only, some allow it to transition across, you know, like any given 2X2 could be in any given array storage configuration. You know, that's not something that we specify. It's something that they do.

Some of the people, like the people have the 22 pages, they say well, we never use all those. And like well, you have them approved so you could at

any time. They're well, yes, they're kind of contingencies, but B- yes, they could be in a mixed. Now, there's multiple different ways of using these now. I don't want to get into all those details. I mean, we could spend at least a day or more talking about all that stuff. I don't know if we want to get into the gory details.

Typically, a nuclear criticality safety analysis of record will have about a half percent margin to the regulatory limits. You know, as the neutron absorber degrades, you know, its initially a compliance issue. I mean, you know, it's B- say well, are you exceeding the regulatory limit? After it degrades, you know, it progresses and starts becoming a safety issue. The more the material degrades, the more we start worrying about how it's going to perform during a design basis event. How is it going to perform if B- during an earthquake? How is it going to perform during a loss of offsite power? You know, how is it going to perform during these design basis events as it gets more and more degraded? And we believe that the key is knowing the condition of your neutron absorbing material so that you can take action.

CHAIRMAN BALLINGER: I have a question. Are there any utilities that now have Boraflex or

carborundum that take credit for it in their spent fuel pool criticality analysis?

MR. WOOD: Yes, sir.

CHAIRMAN BALLINGER: Okay. And we'll get those B-

MEMBER REMPE: A number of them would be nice; just details is what I have been kind of struggling with in some of the material I was provided.

MR. WOOD: Okay.

CHAIRMAN BALLINGER: And I'd also be curious to know what the path forward might be in terms of changing out the material that they use for the neutron absorber.

MR. WOOD: You know, that I couldn't answer what their path forward is. You know, we just approved one licensee for Boraflex credit with a monitoring program going forward presumably, theoretically to the end of the plant license.

MR. CUMMINGS: Kris Cummings, NEI. I can speak to that, and I have that in my presentation.

CHAIRMAN BALLINGER: Oh, good. Thank you.

MR. WOOD: Okay. There's something I wanted to put in because what you'll hear talk about is well, what's the condition of the whole pool? What's the average pool condition? This is just a picture I pulled

out of an event, the Japanese at Shika 1 BWR hd an inadvertent criticality event in their core when they had a couple of control rods drift out while they were aligning the hydraulic control units. And this is just to, you know, point out the idea of B- you know, reinforce the idea of minimum critical volume. It doesn't have to be the whole pool when it goes critical. It's going to be the minimum critical volume. You know, what is the local effects, what are the local areas?

Here they have 89 control rods, three of them moved, none of them moved completely out, but still they went critical in the core for B- and had a power spike.

CHAIRMAN BALLINGER: This is a vessel, this is a reactor core.

MR. WOOD: Yes, sir, this is a reactor core so, I mean B- like I say, I just bring this up is to, you know, like highlight the idea, we're not B- you know, it doesn't have to be the entire core or the entire pool, and it's not B- you know, a pool average for your neutron absorb B- tell me what your aerial density of your neutron absorber is on a pool average. I don't care. I mean, I shouldn't say I don't care, but what's important is the local effects. You know, and if you can't B- you need to be able to tell me what it is

locally, so you need to know what every panel is, not just averages.

So, in summary, you know, when neutron absorbing materials are credited to meet the subcriticality requirements in the regulations, you know, they're unidentified and unmitigated degradation poses a safety concern because the unchecked reduction in margins of subcriticality has the potential to lead to an inadvertent criticality event. And even with that, you know, we regulate to the regulation, and if you're required B- if you're counting on a certain amount of that poison being there to meet the regulation, then it's a compliance issue, and we regulate to the regulation. And that's where we go with that, and that's the first line of defense for safety. And with that, here are some acronym slides. I'll turn it over to Dr. April Pulvirenti. It took me a long time to figure out how to say that.

MR. YODER: Pretty sure you still don't have it right.

MEMBER SCHULTZ: Kent, before we move on.

MR. WOOD: Yes, sir?

MEMBER SCHULTZ: I've got a question associated with the historical experience. Major example is the Boraflex degradation, and although you

mentioned that it perhaps was a surprise at some facilities, for many it was not. I mean, it was noted early on that something was going on that was not expected. The material was behaving differently than anticipated. I'm trying to understand what would be shown historically as the degradation margin that resulted from some B- it could even be a hypothetical time frame delta which would have led to a demonstrable reduction in safety margin.

(Simultaneous speech)

MR. WOOD: B- done those calculations because, you know, it's B- you calculate the instantaneous k effective in the spent fuel pool you would need to know exactly what the status is of every fuel assembly that's in there, what the status is of every neutron poison that's in there, you know, like you would know for the information to do a core analysis. And that B- we just don't track it or perform those analyses to that level of detail.

MEMBER SCHULTZ: But there's a significant margin that was present in those pools. I'm trying to understand, so what could we identify as the change in margin as a function of time that we ought to be concerned about?

MR. YODER: Matt Yoder, NRR. I think that

when we get into Dr. Pulvirenti's presentation, she's going to talk a little bit about the specific Boraflex tools that are in place, and why we've come to a point now where we believe we've got a little bit more uncertainty, and we eroded that margin more than we had in the past. I think that will go towards answering your question.

MEMBER SCHULTZ: It would be helpful, thank you.

CHAIRMAN BALLINGER: And I think the boil it down, we had Margin X a long time ago. It was large. What was it? Now we have Margin Y. We're still okay, but what it is now sort of on average?

MR. WOOD: Well, I don't B- like I said before, if I was calculating the actual margin, now we have an explicit regulation that details what the analytical k effective has to be within 95 percent probability and 95 percent confidence.

CHAIRMAN BALLINGER: But that was this B-

MR. WOOD: Oh, no, this is a regulation. 10 CFR 50.68 B-

CHAIRMAN BALLINGER: Right, but that got translated into this B- into the regulation, but there always was that rule. You needed to have this minimum amount of margin. But what I think Steve is asking is

what was the real margin?

MR. WOOD: I said I don't know that anybody has performed those calculations. We get some estimations that, you know, we're over burn, we're under burn. A lot of those estimations are based on pool averages, not necessarily minimum critical volumes. That's the reason why I bring that out if there is B- you know, people will say is I've got 3,000 fuel assemblies in my pool in BWR, you know, and they're not anywhere near B- you know, most of them are anywhere near the peak reactivity. You know, end of third cycle burned fuel assemblies aren't going to be anywhere close to that. But if you have like half a dozen or a dozen fuel assemblies that are at the peak which would be B- or if you've done a full core offload during your refueling outage, you have a large number of B- I mean, if you do a full core offload during a refueling outage you'll have a large number of fuel assemblies that are pretty close to the peak, you know, at the end of the first burn cycle. So, you know, you're talking about the B- you have the potential for creating B- you have enough fuel assemblies to fill up the minimum critical volume, you know, and if you're not tracking and knowing where your degradations are B- I mean, that is one of the Boraflex degradation strategies was to use the

predictive codes to find out where is the worst degradation, and then avoid that, you know, with some B- you know, like in B- you know, like people would designate sacrificial modules of the pool where B- you know, like a 10X10 module of the pool and say well, this is where I'm going to put my high-dose fuel over here so that it's not B- so that I can count the full Boraflex over there because it hasn't reached its gamma dose threshold yet. They were strategies for going forward and mitigating it, but nobody has actually calculated the actual margin that they have at any given moment.

CHAIRMAN BALLINGER: Maybe we can ping a little bit on the NEI folks when they come because the contention is that the margin is continuously being eroded. I mean, there's a limit, there's a rule that says you have to have this margin, so they always meet that, but the question is what's the trend going forward?

MEMBER REMPE: And when I look at the information we were provided it looks like it's very difficult to really predict the margin in the pool because there's localized effects, temperature flow, whatever that then they rely on BADGER. And what I never could find, so maybe when you're discussing this you can give us is B- I read one part of the reference it

was 40 percent uncertainty in BADGER measurements. And what I'm wondering is okay, so you tune your RACKLIFE code and then you B- based on the BADGER measurements then you do another measurement. And what's the difference B- how good are you even in estimating or predicting what the next time you do a measurement is, because I can't get a feel from that in the information we were provided. I want more details to understand how good we are at doing this at this time. And I don't know if that data exists, but I sure didn't see it in the information we were provided.

MR. YODER: Matt Yoder, NRR, again. Like I said, we're getting ready to get into those specific things in this next presentation, but I'd like to say one more thing on the whole issue of the margin. As you said, it's very difficult to nail down where are you in criticality space. One thing that we would like to do is be able to have a number for a licensee's aerial density of their neutron absorbers, and when they go in and perform a physical test then we will know how close they are to that actual number that is in their criticality analysis. And for many licensees we don't have that now, and that's one of the things that we're striving towards with this Generic Letter, is to establish okay, what is the aerial density of the

neutron absorber that you must have to meet your margin?

CHAIRMAN BALLINGER: Okay. I guess we B-

DR. PULVIRENTI: Okay. I'm Dr. April Pulvirenti, and I am going to go a little more deeply into what Kent was referring to in the technical letter reports that were prepared by the Office of Research in support of the preparation of this Generic Letter.

On the next slide, this is a list of the research products that we have developed. This will also serve as the outline slide for my presentation.

We prepared a spent fuel pool criticality management database which has sort of a list of information per pool. We prepared a technical letter report talking about the phenolic resin materials and their degradation. We prepared another report which focuses on Boraflex and on RACKLIFE, which is the computer modeling method which predicts the degradation of Boraflex, and that report touches on BADGER. And then we prepared a report which focuses specifically on BADGER and the uncertainties associated with BADGER. I'll explain what BADGER is when we get to it, and then I will finish up with a brief description of what Research is doing next.

MEMBER REMPE: What is SuperBADGER?

(Simultaneous speech)

DR. PULVIRENTI: In the slides later B-

CHAIRMAN BALLINGER: Oh.

MEMBER REMPE: I don't see that, and I didn't see it in the report.

DR. PULVIRENTI: Yes. BADGER, there is sort of a Version 1 BADGER which has been in use since I believe 1995-1996, and in the past year or two the vendor for BADGER has come out with a sort of new and improved version. That's SuperBADGER. And as I noted on the slide, the analysis that was done for this technical letter report is of the older version of BADGER.

MEMBER REMPE: Does SuperBADGER still have one source and four detectors?

DR. PULVIRENTI: It has B- I can let NEI, they know more about it, but the main difference is that SuperBADGER has three detectors instead of four. It has new improved waterproofing cable structure, and a little wheel structure on the new heads. But they will go B- they can B- they would know more about the details than I would.

CHAIRMAN BALLINGER: You folks can now claim the mantel as being the first group, earlier group that started using the word B- using snakes and animals, things like that for their codes.

DR. PULVIRENTI: I will admit we B- I had to look up a lot of information in our document database and got a lot of Fish and Wildlife EISes.

So, anyway, the spent fuel pool management spreadsheets, Dr. Ballinger, Dr. Rempe, and Dr. Shack had asked about how these different pools maintain their subcriticality. Research has compiled a list for that. There's over 100 pools in use. We divided it by pool instead of by reactor. How does each pool do it? Some have a very simple strategy, and some have a combination of strategies. That is all listed in this little database. I have the ADAMS accession numbers in these slides. It does not just list only the material, but it also lists whether soluble boron is credited, or control rods, IFBAs, there are other sources of negative reactivity, and sometimes a plant will credit multiple. At my last count, I think there are seven pools that credit more than one absorber. There are something like 22 that credit no absorber, and many that credit some combination and strategy, many of them credit burnup credit and storage patterns, as Kent was alluding to.

In addition to listing just the subcriticality credit, this database will also give a reference for the current applicable licensing

document that is the most recent, because these strategies can change over time as there's either higher activity fuel or degradation. A licensee will change its strategy to respond to maybe a decrease in margin. They change it, so we reference the most recent. Usually, that is the most recent license amendment.

Kent was talking about the different storage patterns. There are so many different complex storage patterns we don't have those in the database. We refer them to the license amendment where they are, and sometimes the technical specifications where they are also listed.

MEMBER SCHULTZ: We have some documentation which has basically screen shots of some of the database which is in 0.01.5.

(Simultaneous speech)

DR. PULVIRENTI: Yes, that was really B- it is readable if you zoom in, and we did have that complaint come in, and it was an error from going from an Excel database converted to a PDF file to go into ADAMS, and we received only one complaint. But if you just zoom in B-

MEMBER SCHULTZ: Two complaints now?

DR. PULVIRENTI: Two now. And you'll see the PWRs you can zoom in, and then the BWRs are at a readable

size.

MEMBER SCHULTZ: Okay, thank you.

MEMBER SKILLMAN: April, let me ask this question. If a licensee chooses to change the method by which the licensee is calculating holding that or poison effectiveness, if that licensee decides to change, is that always a license amendment?

DR. PULVIRENTI: There are cases in which it is not. I can give you one example where it can be covered under maybe not even under 50.59, and that is if a PWR credits soluble boron. In the technical specifications they can maintain that they will have, for example, 2,200 ppm of soluble boron, but in their criticality analysis they say well, we only need 400 of that to meet the regulation.

Now, if they decide to put in a higher activity fuel, suddenly that 400 is not enough and they need to credit 600, they can do that analysis on their own, and change it internally to 600. But because the technical specifications still maintain the 2,200, they do not need a license amendment because B- and that's sometimes they'll see we have so much sufficient margin, and that's because they have it by technical specifications.

Now, there are other licensees who will say

specifically in their technical specifications we must have 400 ppm in case of a dilution event. Now, if they need to change it, now that's a change in tech specs, then they need a license amendment, so it does sort of depend on the B- it is sort of a case-by-case basis.

MEMBER SKILLMAN: It depends on how the license is written.

MR. WOOD: Well, let me B- April is in Research, not in Regulation. The B- right now there's no generically approved methodology or recognized methodology for calculating and estimating degradation and the biases and uncertainties associated with the degradation of any given material. But these are all done on an ad hoc when people come in, so this is one of the issues, is the material is degraded, starting to degrade. The question is, is how do you model that? Those are changes to the methodology in 50.59 that would require a license amendment.

Now, once those get in place we have a methodology for a given licensee on how to do that, how they're monitoring the program, how they're calculating the biases and uncertainties. Then they might be able to adjust for, you know, the modeling of that degradation. But, by and large, it's a change in methodology because those are new biases and

uncertainties that need to be factored into, that weren't included in the original analysis record.

MEMBER SKILLMAN: So, you're saying that 50.59 triggers a license B-

MR. WOOD: Should trigger.

MEMBER SKILLMAN: Should trigger an amendment.

MEMBER SCHULTZ: Are there instances where it has not triggered?

MR. WOOD: Yes, sir.

MEMBER SCHULTZ: Is this part of the concern?

MR. WOOD: Yes, sir.

MEMBER SKILLMAN: Okay, thank you. That was very helpful to me. Thank you.

DR. PULVIRENTI: Okay. This database is accompanied by B- there's two accession numbers, the other one is sort of a little instruction manual technical letter report explaining how we developed the database, and how to read the columns, and what everything means.

This changes all the time. We do periodically update it. Our latest update is for March 2014, and we did that just in time to introduce the newest update for the regulatory information

conference.

Moving on to the next slide, let me briefly speak about the phenolic resins. As Kent said, this is a phenolic B- this is a carbon-based polymer. The B- on the diagram there, that's sort of a generic representation of the sort of bonds and polymer backbone you would expect in the phenolic resins. This is carborundum and Tetrabor. Those diamonds represent particles of boron carbide. This polymer backbone is degraded by the gamma rays, the irradiation in the pool environment, and it fragments this backbone into smaller pieces, at which point that matrix can no longer retain the boron carbide. And that will be lost from the panel through gravity.

In our research on the phenolic resins, we have two major findings. The first is that the mode, the exact mode of the loss of the degradation and the rate of the degradation, how fast this backbone is attacked, depends a great deal on the environment in the pool. The three main environments is you could have either an airtight dry environment, you could have in some cases these panel cavities experience off-gassing so they were vented, in which case you could have a flowing pool water environment, exposure to a wet environment, or you could postulate to have a case where

a panel cavity was vented, but then either later was clogged with products, or very slow, and in which case you may have a stagnant water environment. And these are the possible environments that we found. The rate of degradation depends a great deal on that.

And then once you have a fragmented or degraded polymer, how well does that retain the boron carbide? And what we found is we could find from the data that we have, we could find no relationship B- we could not track the loss of boron carbide to the degradation of the polymer, and we could not track the degradation of the polymer back to say the gamma accumulation because we don't have the environment.

Because we don't have those B- we can't track that through any kind of even semi-quantitative relationship, we have a very limited ability to predict the loss of boron carbide, especially we cannot trace it back to accumulated gamma dose.

On the next slide, I'm going to talk about Boraflex. This is another polymer matrix which encases those diamond representations of particles of boron carbide. This is a totally different polymer. Instead of a carbon-based backbone, this is a silicone-based backbone, no silicone oxygen bonds. This undergoes a well known multi-step degradation.

In the first step for degradation, the first bond to be broken is a silicone carbon bond. Gamma will attack that bond, and those methyl groups will off-gas as methane. That was seen very early on when Boraflex was put in the pool. That will lead to B- the loss of that bond will lead to further cross-linking of these polymer chains which leads to shrinkage of the material which is a slight reapportionment of the boron carbide particles. It also leads to some gaps across the panel. I have an illustration of that later.

After the cross-linking and shrinkage, the gamma continues to attack the polymer, since it went after the pendant methyl groups it now attacks the silicon-oxygen backbone. Kris Cummings from NEI passed around a very flexible, almost like a black gasket. When this backbone is attacked by gamma rays, that begins to stiffen and become brittle, and more like sand. In fact, literally more like sand. It turns from a silicone flexible backbone to a reactive silica particles which are slightly soluble in water.

That leads to the next step, flowing pool water will dissolve these slightly soluble silica particles. And as that matrix degrades, and as silica is lost from the panel, the boron carbide is lost, as well.

Because this is slightly soluble, the dissolution and removal of the silica happens on the orders of years, and sometimes decades. And this is why it was many years before this degradation was detected, because it's very B- the rate is pretty constant but it is pretty slow.

Moving on to the next slide, I was talking about how we could find no relationship between loss of boron carbide. We could not trace it to gamma dose or the phenolic resins, carborundum, Tetrabor. However, for Boraflex it can be tracked. There's a proportional relationship that one can trace the loss of boron carbide to the loss of silica, the loss of silica can be traced to the attack of the backbone, the attack of the backbone can be traced back to the accumulated gamma dose. This is what the RACKLIFE computer code is based on.

There are two main parts to RACKLIFE. The first part is that RACKLIFE will calculate based on the history of assembly movement in the pool for each panel. It will calculate the accumulated gamma exposure that's attacking the backbone.

And then moving into the next part of the model, and a much more complex part of the model, the available silicon oxide is the part that's dissolved,

that can be described by a silica transport model. It's a kinetic model of many different equations. The illustration you see here is a very simplified version of that. There are two main portions on this illustration. The first you see on the top is the panel cavity. That's the panel inside the rack, and then the bottom dotted box you see is the bulk pool. The silica transport model traces all forms of silica, and what it can do with its rate constants. And from that we can calculate how much silica is lost, calculate that from the accumulated gamma dose, and then that can extrapolate very quickly to loss of boron carbide.

One more thing I'd like to mention on this is that all of the arrows, you can see there's four of them going across that travel from the panel cavity to the bulk pool. Those rate equations have sort of an overarching rate constant to them. That is known as the escape coefficient, and I will talk about that on the next slide.

CHAIRMAN BALLINGER: In my business, they call that a fudge factor.

DR. PULVIRENTI: Yes, I have B- our contractor expert has used that term.

PARTICIPANT: Highly technical description.

DR. PULVIRENTI: On this next slide, I'm going to go a little bit more into what happens in the panel, and how this relates to the uncertainties in this calculation. The calculation has several major inputs, one of them is the measurement of the bulk pool silica, and through the accumulated gamma dose which is calculated for each panel RACKLIFE can deconvolute and partition a total silica value in the pool and sort of apportion it through the accumulated gamma dose and calculate a total silica loss and, therefore, a total boron carbide loss for each panel in the pool. So, it can calculate 3,000 panels, but only at panel resolution. It does not recognize within a panel, only on the resolution of a full panel.

This is the escape coefficient, again. This is in B- the units of this are panel cavity exchanges per day. To explain that, I'll go over to this illustration here. Water enters the panel from the bottom and by convection it is drawn upward and exits the panel at the top. If it takes one day to go from the bottom to the top, that's known as exchanging one panel cavity volume. Your escape coefficient would be one. That's what's meant by those units.

The very simplified scratching the surface of what RACKLIFE does is it calculates what it believes

that the silica value in the bulk pool would be, and then it takes the panel B- the measurement of the bulk pool silica that it actually is. They compare the two, they adjust to this escape coefficient so that it matches, and then they can run their model again through their accumulated gamma dose and the silica and thus calculate through several equations the boron carbide loss for each panel in the pool.

The uncertainties are that the pool silica measurement is affected by the filters, it's affected by the flows. Of course, it's totally cleaned out for every refueling outage because they don't want silica going into the RCS, so that may not be accurate, and certainly not to three to four significant figures. If the escape coefficient is not tuned or not tuned often enough, that can give you a very large uncertainty, and that's summarized in the reports. That can be upwards of 20 percent.

And as time goes on, our last uncertainty on this slide is the non-uniform degradation. This is significant because this uncertainty increases with time, that RACKLIFE does not recognize non-uniform degradation on the panel. And I have it here in the illustration, you can see the sort of white lines going across. Those are those gaps due to shrinkage. And then

over on the side you can see a scallop. That's if you have a local rivet, you can have local degradation. These local dissolutions become important because now your flow path instead of tracing a uniform flow path sort of slow and constant across the entire surface of the panel, you now start seeing preferential flow paths through parts of the panel. And you can see that curved line is a flow path going across the scallop.

If you have a non-uniform flow path and the model assuming a uniform flow path, as time goes on, as degradation becomes less uniform, and as these flow paths become more dominant, that is a departure from the model, and so the model is less matching what actually goes on inside this panel cavity, and that increases the uncertainties over time.

In our report, the figure that we have is that these are very, very rough numbers, that around 20 percent degradation is when these flow paths begin to deviate from the model. And at about 40 percent degradation of the panel, that's when the model begins to be unreliable.

MEMBER SCHULTZ: So, April, when you say it begins to become unreliable, are we talking about B- is that when we're talking about an uncertainty?

DR. PULVIRENTI: It's almost B-

MEMBER SCHULTZ: An uncertainty of let's say 20 percent, or 30 percent, and what would not give credit for the material beyond that.

DR. PULVIRENTI: We actually B-

MEMBER SCHULTZ: Or we just don't know?

DR. PULVIRENTI: We just didn't B- we don't know at that point. Even the uncertainty becomes uncertain at that point.

MEMBER STETKAR: I'm sorry. How is uncertainty uncertain?

MR. YODER: We're uncertain about the B-

DR. PULVIRENTI: The level of uncertainty.

MEMBER STETKAR: Don't be glib on this. The Staff traditionally does an extremely poor job in evaluating uncertainty, so I really want to understand what you mean about the uncertainty becomes uncertain.

MR. YODER: Well B-

MEMBER STETKAR: You always explicitly evaluate uncertainty.

MR. YODER: Well, I can give B- maybe go to examples where we've had licensees who are running these programs, and performing in situ tests which we'll talk about next, the BADGER test. They thought they had a good handle on the material condition. They have reached a point where they have crossed this 40

percent threshold, and where they thought they were was far from where they were on their degradation when went in and actually did an in situ measurement.

MEMBER STETKAR: So, all that means is they didn't evaluate the uncertainty properly.

MR. YODER: That's correct.

MEMBER STETKAR: Okay. But that doesn't mean you're uncertain about the uncertainty. It means they just didn't do it right.

MR. YODER: It is difficult to quantify the uncertainty.

MEMBER STETKAR: I didn't say it was an easy process.

MR. YODER: Maybe that's a clarification of uncertainty of uncertainty. Is that a better description?

MEMBER STETKAR: It is important in these analyses because you're postulating things that could occur without providing any estimates of their likelihood or your confidence in those estimates. Just keep that in mind.

MEMBER SCHULTZ: Let me ask the question differently. Is what you're trying to depict here features that are not in the model of predicting degradation, or these are features in the model that

are not very accurate?

DR. PULVIRENTI: By the feature, you mean these non-uniform flow paths?

MEMBER SCHULTZ: All of what's show in the diagram there, are these the types of things that are intended to be incorporated in the model predictions that you said B-

MR. WOOD: May I just speak to that a little bit for the analysis? The RACKLIFE predicts uniform degradation only, uniform thinning loss of material across the entire panel for the panel average top to bottom. That's all it does. What is actually going on in the panel are these other non-uniform B- in addition to the uniform thing that is going on, you start having non-uniform degradation mechanisms that are going on. The scallops are forming, you have the cracks that are formed, the cracks start getting eroded, they start becoming bigger, you have areas that B- you know, water B- you know, although it's depicted here, these wrapper plates hold the panels in place. They're not sealed, and there's tack weld, so water can actually come B- depending on B- water can get in at any point and that's, you know, it could help exasperate the scallops. So, as that starts to C- as these non-uniform aspects, the uniformities of the panels start to build

up that makes the prediction of the actual degradation of that panel less and less certain from the computer code because it can only model, you know, the uniform prediction. You know, the flow rate is increasing, all these things are increasing, the escape coefficient is increasing. As the panel gets thinner the escape coefficient goes up because there is less resistance to flow.

You know, all these things are coming into play, and as we get further and further away from the pristine sample where you start getting more of these B- like the computer codes, you know, you start getting the drift on the computer code, like how well do you know what it's really telling you?

We had licensees, and I'll get a slide for that later about where they try to take the uniform prediction, do an equivalency to the non-uniform aspect to try to come up with what the reactivity, net reactivity effect is, and then model that in an analysis. You know, and that's the type of things that we're dealing with.

What we're saying is, you know, it's like if you're sailing down B- you know, you got a set and drift on your sailboat. You know, if you don't correct for that, then you keep on going further and further

off course. And that's what we're trying to say, as you get further and further down the degradation path these predictions get less and less certain. And the amount of uncertainty becomes harder and harder to quantify because you have these effects going on. You can't see exactly what's going on in the panel. You don't know what the actual panel looks like. You don't know what the actual escape coefficient is of any given panel. You have 3,000 panels that you're trying to model. You can B- you know, like it's my understanding that you can tune the escape coefficient for each panel, but takes a ton of work to go in there. And then it's an educated guess as to what the escape coefficient for any panel is anyway.

CHAIRMAN BALLINGER: But RACKLIFE does not calculate uniform degradation, it calculates total degradation, and you assume that it's uniform. Right?

MR. WOOD: No, no. It predicts B- the only thing that RACKLIFE calculates is silica loss, which is correlated to B4C loss.

CHAIRMAN BALLINGER: Right.

MR. WOOD: And that's completely uniform. It does not take B- you know, it would not calculate B- include the effects of this additional washout by scalloping.

CHAIRMAN BALLINGER: I understand that, and that basically just expands the uncertainty.

MR. WOOD: No, that's B- those are total C-- those are part of the total degradation package which RACKLIFE is missing. RACKLIFE only calculates the minimum or the uniform thinning, the uniform loss of material across the whole panel. It does not calculate in any way, shape, or form these scallops.

CHAIRMAN BALLINGER: I think we're saying the same thing.

DR. PULVIRENTI: Yes. If I could clarify. RACKLIFE calculates the loss of X amount of silica from X panel.

CHAIRMAN BALLINGER: Right.

DR. PULVIRENTI: And it bases it on panel resolution because it calculates, it traces it back to how much gamma exposure. And the gamma exposure is only calculated per panel. It does not say that the one-half of the panel had more gamma than the other. I think they only can calculate it on fuel movements.

In the early iterations of RACKLIFE in the early '90s, in fact, computing power was a limitation, so they actually did not have the computing power to use any more than one escape coefficient even though it could be different. So, they used the same escape

coefficient, and that's another source of uncertainty.

MEMBER REMPE: In addition, some of the information we read that was provided to us discussed a bit about the fact that the shrinkage and the scalloping actually can increase localized effects, can localize the activity. It's viewing factors, and is that not the case, and do you want to elaborate a little bit about that?

DR. PULVIRENTI: You say increased reactivity?

MEMBER REMPE: Basically, you have B- the fuel can see each other more easily, and you could have localized effects that way.

DR. PULVIRENTI: Yes.

MEMBER REMPE: Which is not covered by any of the RACKLIFE analysis.

DR. PULVIRENTI: It was not covered by these gaps that you see, those lines. That I think is what you're talking about. What happens is that B- it's like having a blanket shrink in the wash. Now imagine nailing the blanket to a board and then shrinking it in the wash. It's going to shrink, but where those nails are it's going to stretch because that's the tension on it. And that's exactly what's happening, and that is one of the reasons that these gaps tend to show up straight across,

is that that is where the panel or Boraflex is riveted, or stapled, or otherwise adhered to the rack. And then when it shrinks and pulls away, that's where the shrinkage occurs.

MEMBER REMPE: Is it 10 percent of shrinkage? Is it B- how much is the shrinkage and when B- for localized reactivity concerns?

DR. PULVIRENTI: We don't have an exact number. I believe it is a 4 percent I think by volume B

MR. WOOD: She's asking two different questions. The cross-linking, the gamma cross-linking shrinkage is max B- it's a maximum of about 4-1/2 percent.

MEMBER REMPE: Okay.

MR. WOOD: Okay? And after that, then you continue to get dissolution, and where those gaps or cracks that have occurred, you can continue to get washout as the water flows through that, like eroding a river.

Now, the scallops and additional non-uniform degradation where RACKLIFE may predict you have 20 percent degradation, you may have spots where you have 30 percent, you may have spots where you have 10 percent. Where those occur they do increase, you

know, the neutronic communication between adjacent fuel assemblies. And that's one of the concerns that I have as a criticality engineer is that scallop that you see there, I mean, that B- they're just B- neutrons are just streaming right through there. That's an open spot, so that's increasing the neutronic communication between adjacent fuel assemblies. So, that's part of what I had said before is, you know, the attempt is B- you know, the RACKLIFE code will predict uniform degradation. There's actual real degradation that's going on in addition to what RACKLIFE is telling you that needs to be accounted for in your criticality analysis. It becomes very difficult.

I'll bring some slides back on a break that I have, some backup slides for talking about some of the stuff. We can talk about that a little bit more. But, you know, right now it certainly is a concern, and that's part of the problems with this issue, with this particular material so far.

DR. PULVIRENTI: Okay. So, Kent, I'm on the next slide.

MR. WOOD: Certainly.

DR. PULVIRENTI: I'm going to move on to BADGER. As I noted earlier, this is the original BADGER meaning four detectors and in general Boraflex in the

calibration cell that I'll expand on that a little bit later.

This is the boron aerial density gauge for evaluating racks, always have to have the acronym. The diagram on the left gives a pretty stylized simplified version of looking at the sort of a side view of the pool. You can see the rack. This is an in situ method. This does not calculate B- well, it does not model by computer model what the loss of boron carbide is. It does measure it through the neutron attenuation.

The BADGER instrument is two heads, one is a source head, and the other is a detector head. The source and detector heads are lowered together, and let me move over to the figure on the right showing now we're looking above that rack. You can see that the source is lowered into one cell. The detector head with the detectors are lowered into the cell next to it, and that panel in between is what is being measured.

Unlike RACKLIFE, this does give spatial data, and it goes see non-uniform degradation. The heads are originally lowered to the bottom of the pool, not the bottom of the pool, the bottom of the rack, the bottom of the panel. A scan is done. The heads are lifted about two inches, and a scan is done, and it's lifted two inches, a scan is done all the way even a little

bit above the top of the panel. Because it only measures the panel in between it does not B- it is not specific to Boraflex like RACKLIFE is. Any material can be measured by BADGER.

MEMBER SCHULTZ: In other words, it's just B- it's measuring the full neutron B-

DR. PULVIRENTI: Yes.

MR. WOOD: It measures full neutron attenuation between the B-

DR. PULVIRENTI: Neutron attenuation. It does not even know if material B- it doesn't even know if the polymer is there. It doesn't even know what the material is.

MEMBER SCHULTZ: And that's fine.

MR. WOOD: And they are used to calibrate the counts that you get on site. Before we go on to the next slide, we mentioned SuperBADGER. As far as this picture, you know, the major changes you would see on this picture over here would be instead of four detectors it has three basically in the gaps here. And there's also B- the detectors are a little bit larger to address some of the issues that were in our technical letter report. They've also got ball bearings here on springs to control head alignment. Once again, to address some of the issues in our technical letter

report concerning the initial BADGER version.

There are some other changes throughout, but as far as the picture goes you have three detectors instead of four, and you have the ball bearings here to control head alignment.

MEMBER RICCARDELLA: Why is three an improvement over four?

MR. WOOD: I think what it is, they made them bigger. Also, they're not just B- there's three and they made them bigger, so I think there might be a spacing issue. I think in the details of the design for that perhaps we can get the NEI presentation, they can provide that information.

MEMBER REMPE: But maybe this could also wait until the NEI folks, but the Oak Ridge report said that BADGER had uncertainties up to 40 percent. Is computability B- I mean, do you see 40 percent difference and you try and do a scan, and then you do another scan. Is it that far off?

DR. PULVIRENTI: I'll have to go on and address that when I get to it, if that's okay. So, anyway, on the next slide just for those not familiar, this is B- this shows some B- now, this is not the raw data. This has been sort of processed through B- but what this is showing again, here's our four detectors

starting from the bottom of the panel, and as these detectors are lifted up through the elevation of the panel, there's I think 72 scans that are done every two inches to cover the entire panel. And any time you see a peak that's a neutron B- those are neutrons streaming through, and that corresponds to a thinning, or a gap, or some kind of a hole in the panel. And over on the right you can see sort of a 2D representation. That's more of a computer calculated picture. That's not an actual photograph of a panel. This does B- this is Boraflex. You can see now in this case the black is the gaps. And you can see the peaks, you can see at the top there are some pretty large peaks. That corresponds you can see to the gap. There's another one down near the bottom, and then in the middle you can see some smaller peaks. And that's also corresponding to either some thinner gaps, or gaps that did not go all the way through the panel, just more stretched thinner pieces of the panel.

On the next slide, let me start going into the uncertainties. In BADGER, first of all, the B- because they do 72 scans in the space of around half an hour, they can have very low count times. And low count times means low counts. Low counts means that any impact that would introduce uncertainty into the count

is even a little bit more uncertainty. For example, the source head moderator pool conditions, flux trap racks are very uncertain for BADGER because now you have two panels and a water gap, not just measuring the panel in between. So, that's very uncertain. So, that's low neutron counts that can be B- there's count uncertainty even in just the counts alone. The Oak Ridge report gives an uncertainty of plus or minus 8 percent. That's based on count rates as low as 200 counts on one of these scan B- one of these step scans.

The gamma interference, there's B- these instruments B- these measurements are done in a living operating pool, so there are a lot of fuel movements. They have to move assemblies away from the panel that they are testing, but in cases I think that the nearest assemblies can be something like 18 to 24 inches away, two to three rows. There is still gamma interference from the surrounding assemblies. That introduces a lot of interference because pulse pile-up can give you either a false negative or a false positive neutron, which is incorporated into the calculation. The figure on the right is an illustrative figure. These detectors are boron trifluoride. This just happens to be a helium counter but it's the same sort of concept that as more gammas are interfering with your measurement, the

spectra begin to overlap. And if the discriminator is not set correctly, that will introduce a great deal of uncertainty into your calculation. And this speaks to Dr. Riccardella's question about the detector size.

If there's a small detector, the pile-up pulse is a B- the effect of that is exacerbated and the wall effect is exacerbated because a small detector will have a higher proportion of wall surfaced area to the detector volume. And one way to address it is to decrease your number of detectors and make them larger to give you a larger volume of boron trifluoride gas.

MEMBER SCHULTZ: I thought at one point you said that the typical approach would be to allow a count time of 30 seconds at each elevation. Now you say count times of 10 seconds may result in low neutron counts.

DR. PULVIRENTI: Yes, that actually varies. That has been varied over the years. There does not appear to be a set standardized procedure, at least not for this original BADGER. That if they got a lot of counts, they said we have enough, let's move up, so that was done on sort of an ad hoc basis in this earlier B-

MEMBER SCHULTZ: Why would that not be okay? The counts might be coming from other areas of the pool, you're saying?

MR. WOOD: You know, low count rates give

you, you know, like poorer statistics. And then depending on B-

MEMBER SCHULTZ: Right. I understand that.

MR. WOOD: So, I mean, you know, it's B-

(Simultaneous speech)

MEMBER SCHULTZ: I would like to understand why there wouldn't have been a protocol established.

MR. WOOD: Perhaps there was a protocol that was used that was not reviewed and approved by the NRC, or even commented on as far as I can tell. You know, we did B- April and I, and other NRC personnel went to a licensee and watched them do SuperBADGER tests last year, you know. And we watched several runs of the tool and observed that in action. We didn't watch the entire 14-day campaign. You know, as we come back and we get the report later and we're reviewing that, there's some anomalies on there that leads to questions. And during the course of the campaign, they changed the dwell time for how many counts there are. You know, it could be B- certainly getting more counts give you better statistics, so we listed uncertainty in our technical letter report about the tool as being a concern, so they're trying to address some of that, so they have a higher dwell time. You know, the idea is to drive the statistics down to an acceptable place and then you can

move on, but what they had done is they had changed the dwell time because they were running out of time, so they expedited some of the measurements.

You know, all that stuff in going to B- you know, it can be acceptable but it is a source of uncertainty that we look at, and that needs to be addressed or considered in the protocol for using the tool.

CHAIRMAN BALLINGER: Okay. We want to make sure that we have B- we get the full presentation, but we are running a little bit behind.

DR. PULVIRENTI: Okay. Well, I only have three slides left. Kent, I'm on the next slide. Continuing on with the BADGER uncertainties, this is a BADGER is not a purely calculation, the calculation of boron attenuation is done through a calibration curve, a calibration assembly which represents an egg crate, or a flux trap is lowered into the pool, and a calibration curve is run before each BADGER campaign. And then the subsequent panels after being tested are simply calculated to that standardized calibration curve.

Now, in the calibration there are several uncertainties. First, you have a non-linear curve so the number of points on the curve better describe the

curve. If you only have five standards you only have five points on a non-linear curve. That's a source of uncertainty. There's a potential for material mismatch and this is B- for example, in some of the earlier versions of BADGER a calibration cell B- even though BADGER is independent of material, the material condition does contribute some of the uncertainty. For example, if you have a Boraflex panel with non-uniform degradation in the calibration cell and you have a B- you're testing a carborundum panel with unknown degradation, there's some uncertainty in the material mismatch between the calibration numbers and the subsequent test numbers.

There's a B- boron carbide at least in the earlier version was calculated as a loss compared to a panel that was assumed to have no loss. That's the zero dose panel was used as the sort of nominal maximum reference, and there's uncertainties if that had B- if something you thought didn't have loss actually did. And then there's the effect of the flux trap going through two rack walls and two panels and a flux trap in addition, instead of just one panel, so there's uncertainty there.

One of the largest, as Dr. Rempe was talking about with the 40 percent uncertainty, that is

due to head misalignment. That's just one source of the uncertainty, the 40 percent is from head misalignment alone. Because you B- because these cells are packed almost as closely as B- the assemblies are almost as close as they are in the reactor, these two heads are within inches of each other, so even a small angle misalignment will introduce an uncertainty into the neutron scatter from the source head to the detector. This diagram pretty much speaks for itself with the different types of misalignment. You can see the proper alignment, you can see an offset in sort of a Y direction, you can have a twist, and then the bottom the tilt that's sort of taken from a different angle, but you can easily see how these two heads if they're not perfectly flush can cause a fairly high uncertainty.

In addition, there's no realtime detection of misalignment. This is done in a pool. This is under 30 feet of water. You have distortions, you have parallax, so detecting a one, to two, to three degree misalignment, of course, is very difficult. A very skilled operator doing the calculations may see an anomaly in the calculations later, and someone very experienced could say hmm, that looks like it's been a head misalignment, but that was done B- the panel

scans were done during the day, much of the number crunching was done at night, so a head misalignment if detected was detected after-the-fact, and scans were generally not repeated because they only had a certain amount of time at the pool to do a certain amount of panel scans.

MEMBER REMPE: Have they ever been repeated, and what's the difference that they would see in a repeat measurement?

DR. PULVIRENTI: That's a long answer I can get you, but that was in the B- that is in the reports. We did look at that. A few panels have had some B- very few panels were repeated during the same campaign.

MEMBER REMPE: Okay, but if they were, were they 50 percent off, 100 percent off?

DR. PULVIRENTI: The uncertainties in this were high, that I think the way our contractor explained it is the uncertainties were high, that even the difference was uncertain.

(Simultaneous speech)

MEMBER REMPE: Is it 100 percent? I mean, what was the number?

MR. WOOD: You know, I can speak to the old times. You know, we went and we watched the SuperBADGER test last year, and they did repeat about a half a dozen

scans. And there was a significant change from the first scan to the second scan.

MEMBER SCHULTZ: What significant change?

MR. WOOD: Significant? I was B- they were B- the count rates came down probably, or their indication of degradation or their transmission ratios were about 30 percent lower than what they were, indicating that there was more material present then the initial scans were. And they did that across the board.

They made some changes to the tool to address some of these issues that were identified in the technical letter report. I would say that having seen it, there are some improvements. I don't know that B- we haven't had a chance to review the new tool and its data. It's only been in use for a year. So, right now what those uncertainties would be is the repeatability was a concern. That's one of the reasons why they went back and redesigned the tool to improve some of those conditions. That was being requested by their customers. And because we were asking them questions about the repeatability, what their answers were, you know, and so how do they justify the use of these tools to like model the neutron absorbing degradation, the aerial density in their criticality

analysis? So, they come back and the customers have asked for that. They've worked on that. It's improved. We don't have a lot of data on the new tool to say what it was. As far as the old tool, I don't think we went out and put a number on what it was because we didn't have the raw data to make those analyses.

MEMBER REMPE: But you saw something that implied about 30 percent difference.

MR. WOOD: That was from that one test.

MEMBER REMPE: Right.

MR. YODER: According to B- from Staff observations unofficially we have notes, approximately 30 percent on a rescan. Does that sum it up?

MR. WOOD: Well B-

MR. YODER: For the new tool.

MEMBER REMPE: Okay, thank you.

MEMBER RICCARDELLA: And it was consistently downward B-

MR. YODER: Yes, sir.

MEMBER RICCARDELLA: The second scan alwaysB-

MR. YODER: Yes, sir. For that specific test campaign and for the guy that was operating the tool that day, that was the one specific scenario. That's not to say that every time you go on a campaign it's

going to trend down. Something changed between the first and the second scan that day that resulted in that trend.

MR. WOOD: What they're doing for the scan is for, you know, if they're scanning the calibration B- they're doing some things differently than what is in our technical report. You know, they've got the ball bearings on the head to address the alignment. They've got the three detectors to change the head pile-up and the head count rates and wall effect, so they're trying to make some improvements to get into some of those areas. What they were doing, this licensee for this campaign is they were making a calibration scan in the morning, and a calibration scan in the evening when they were done for the day.

MEMBER SCHULTZ: And this had not been done previously, calibration scans B-

MR. WOOD: No, calibrations were typically scan B- done once a day. They wouldn't necessarily catch any drift during the course of the day.

MEMBER SCHULTZ: Okay.

MR. WOOD: On some days the scans on the calibration panels would be, you know, very similar, virtually identical. Other times there would be, you know, 10-15 percent difference of a scan of the exact

same calibration panel.

DR. PULVIRENTI: And I'll just say with the older version they did begin by calibrating more often during the campaign, and then when they found that the calibration did not change, so they reduced the number of calibrations. And I think when they had experienced operators who were able to B- this is according to the contractor. When they got sort of better at it, this is the older version, they were able to go down to one calibration per campaign because they found the other calibrations did not introduce a difference, but that's what we were told. This is the earlier version of BADGER.

I'm on the next slide, Kent. By the way, Matt has graciously offered some time from his presentation.

This is uncertainties not so much in the measurement itself, but in the sort of global use of BADGER. RACKLIFE can only calculate an entire panel, but it can give at least a separate number for all of the panels in the pool, 3,000, 4,000 numbers in the pool. BADGER is kind of the other way, it knows one panel really well, but it only knows that panel really well.

A typical BADGER campaign will test between 30 and 60 panels. In years past that number has

sort of come down, partially if they're limited by time, or they could be limited by the number of fuel moves that a pool agrees to do. Remember they have to move fuel away and trying to test 60 panels is a lot more fuel moves than testing 30 panels. So, we have 30 to 60 numbers out of a pool that's 3,000-4,000 panels. How do you extrapolate those results? How do you even select which panel to scan? For Boraflex B- oh, I'm sorry.

MEMBER RICCARDELLA: This doesn't have to be done during an outage, does it? Is this done during an outage?

DR. PULVIRENTI: This is not done during an outage.

MEMBER RICCARDELLA: So, why is there such a time limitation?

DR. PULVIRENTI: That might be addressed to industry.

MR. CUMMINGS: Yes, I can answer that. The pool are very time oriented and the time that they have in their spent fuel pools they're doing all sorts of things. They're doing fuel movement to dry cask storage, they're doing other things in the pool. There's been some presentations to the NWTRB about the actual amount of time in pools that's available. Say, if they refuel every 18 months there may be a 12-week

window total in that 18 months where they have time to do other things than what's already been planned. So, there's not a lot of time. The time in the pools is very valuable.

DR. PULVIRENTI: I did a back of the envelope calculation and a pool could be doing fuel moves for a month just to prepare for one of these campaigns. In addition, these campaigns are generally 10-14 days. The source is a Californian source which has its own fairly short decay life, and over a 10-day campaign you have a .7 degradation of the source itself, so that's another consideration.

So, even the panel selection is uncertain. For Boraflex we have a predictive method. They can B- even with the uncertainties RACKLIFE can at least rank good panels, medium panels, bad panels in the pool and, thus, select which panels to scan by BADGER in a Boraflex pool. In a Boral pool, or a carborundum pool, or Metamic pool there is no predictive method that is used. In fact, that's B- the panel selection is more of an industry question. But trying to extrapolate the small amount of panels statistically to an entire pool is the source of uncertainty that we're trying to look at.

MEMBER REMPE: So, when they do this, which

panels are going to be good, medium, and poor B-

(Simultaneous speech)

MEMBER REMPE: And that is what I was trying to ask earlier, you know, they use RACKLIFE to predict what's going to happen the next time they do a scan and how good are those predictions?

DR. PULVIRENTI: We asked the contractor that. He gave an all-day seminar to us.

(Simultaneous speech)

DR. PULVIRENTI: We asked him that question, and he said at least in all of his years up to about 2001 the RACKLIFE rankings helped. That if they ranked the panels, BADGER B- there might be uncertainty within those rankings, but they never got two panels to cross, so to speak, that the BADGER ranking generally matched the RACKLIFE ranking. But that was I should note as of 12 or 13 years ago with Boraflex. We've had 12 or 13 years more of non-uniform degradation, so the uncertainty has been increasing since then. That's for a Boraflex pool. For other materials it's a big unknown.

CHAIRMAN BALLINGER: I'm assuming red means bad?

DR. PULVIRENTI: Yes. And this is, I believe, another Boraflex pool.

MR. WOOD: Red may not mean bad. It's just

color coding the amount of degradation B-

DR. PULVIRENTI: It means the amount of degradation, and when they can calculate through RACKLIFE they've employed quite a few strategies to know what their bad panels are. And there is some detail in that, they can move to a different storage pattern, they can give up certain modules for lost, so to speak, and just checkerboard those. There's different things they do, so they do need to know the degradation. And this is the Boraflex panels, again. Other materials are woefully unknown. Boraflex at least has a predictive method that can give some quantitation.

Okay. I'm on my B- so, that's the technical letter reports. This is my last slide. This is what Research is focusing on now. Research chose to focus first on Boraflex and carborundum because those were the materials with the most degradation, and the most I guess you could say licensing activity, so we chose to focus on those first. Now it's time to look at Boral.

We are working with EPRI, the Electric Power Research Institute. One of the ideas that we had was to go to a decommissioned plant and actually look at, because we have not had an instance B- we do not have any data whatsoever of say a BADGER scan on a panel, and then a destructive examination of the same panel.

We have none of that.

This is our chance to do this. Zion is a decommissioned plant. It's near Chicago. The pool is still operating. As we speak they are casking their assemblies, so the assemblies are in the process of being removed from the pool. I'm working with EPRI right now. We are coordinating an effort to do two major research activities. One of them is that the makers of SuperBADGER are going to go to Zion and they're going to do BADGER scans on some of the panels there. They're currently in their panel selection. They're basing it on different variables in the pool and the gamma exposure. They're doing calculations to do their panel selection. They're going to analyze I believe about 30 panels by BADGER, and this is during the casking period, so Zion has agreed to suspend casking while they do the BADGER campaign. NRC is planning to observe.

And then next B- late next spring after the casking is completed there will be a window of time when the rack modules will be empty, but they haven't demolished the pool yet. During that time somebody is going to harvest the exact same panels that the BADGER was done on. That will be analyzed in the clean pool at Penn State and I believe by chemical analysis so we will finally have some kind of a match between an actual

panel, destructive exam of the panel, a clean pool exam of the panel, and a BADGER scan of the panel and have some real comparative numbers. So, that's what we are coordinating right now, and I'm finished.

MEMBER SKILLMAN: I would like to ask B-

CHAIRMAN BALLINGER: Oh, go ahead.

DR. PULVIRENTI: Okay.

MEMBER SKILLMAN: B- just two quick questions. On your image on slide 30.

DR. PULVIRENTI: Yes?

MEMBER SKILLMAN: Not too hard to imagine that the red represents perhaps two things, the location of the most irradiated assemblies in near term time frame. That's an offload.

DR. PULVIRENTI: This is Boraflex, yes.

MEMBER SKILLMAN: Plus temperature. I'd be curious to what extent temperature has been considered in the uncertainty. But let me ask my second question. This BADGER is a relative attenuation device, not more than that. That's really B-

DR. PULVIRENTI: Yes.

MEMBER SKILLMAN: And determine relative attenuation. And its ability to understand that is based on the setting on your BF3s.

DR. PULVIRENTI: The discriminator, yes.

MEMBER SKILLMAN: The discriminator. And these are the old source ranges that have been used since Moby Dick was a minnow. I mean, this goes back to the Nautilus. So, unless that bias is set correctly on the BF3s anybody can get any reading anybody wants. So, when you mentioned the campaign with the consistent 30 percent set down, I'd be curious whether or not that really is an accurate relative attenuation, or whether the calibration on the BF3 bias is what it's supposed to be. So, it seems that there are other uncertainties that need to be exposed before we all sign on and say by golly, we've got a tool that we can take to the bank. Temperature and uncertainty on the BF3s, it seems that those are real uncertainties.

DR. PULVIRENTI: I can address temperature. As I had said earlier, in the earlier days of RACKLIFE they were limited by computing power, so they could not use temperature as a variable. They knew that the temperatures were higher in local portions of the pool, but they could not incorporate that into the RACKLIFE program because they're still using Windows 3.1 and little Apples, and that sort of thing.

In a later version of RACKLIFE a temperature model was introduced but, Kent, you can answer. I believe that was never used B- never depended

on in a license B- an approved license amendment.

MR. WOOD: Well, that part is true. The idea of adding the temperature dependence came along later. The licensee was trying to add the temperature dependence, use the version that had a temperature dependence on it. They were called out on that by the Resident Inspectors about that being a change in methodology from the approved tool, and it hadn't been reviewed and looked at. You know, temperature will correlate with dose. I mean, the higher the gamma dose, the higher the temperature is going to be until it B- because they are tracked with a k dose. I think they can track to the k dose, so they can get a correlation with temperature. So, if you're modeling temperature you're really trying to model it twice with dose.

The discriminator, you know, that's a concern. That's a field adjustment that they make. I'm not an instrument guy, so how you qualify how much of an adjustment to make, what's enough, what's not enough, I certainly share that trepidation with that adjustment. You know, we rely on the licensees to do the measurements when we're not watching them in a professional manner, that they wouldn't do something like that. That they wouldn't, you know B- what you're suggesting is they could game the system to get the

answer they want.

MEMBER SKILLMAN: No, I was not attempting to communicate that.

MR. WOOD: Okay.

MEMBER SKILLMAN: I was not trying to be pejorative. What I'm saying, though, is unless that bias had been gained to set consistently from one day to the next you could get a very different reading out of the BF3s. So, they will respond based on that gain. That's my point. So, if on a certain day the operator is getting significantly reduced, if you will, attenuation, a significantly greater attenuation the question I would ask is, is the BF3 set consistently?

MR. WOOD: You know, that's a good question. We don't typically B- that level of detail is not typically in the reports that come out with those campaigns.

MEMBER SKILLMAN: Additionally, perhaps, to the uncertainty that Dr. Rempe was talking about.

MS. GAVRILAS: If I can interject here. The Oak Ridge report that we have B- this is Mirela Gavrilas from Research. The report for BADGER does include the electronic setup, so one of the objectives that we have in observing SuperBADGER is going to be observing how the pulse is traced through the electronics, and what

the criteria are for setting discrimination getting and so on. So, what exactly do they do? If you look at the slide, the BADGER uncertainty slide that April has shown, we're trying to understand where exactly they choose to put the threshold on that slide. Does that help?

MEMBER SKILLMAN: It does, yes. Thank you. I was not attempting to suggest inappropriate behavior by the operator. What I'm saying is how that BF3 is adjusted is very, very important. And if it's not consistently adjusted, then the readings will be different. That's my only point.

CHAIRMAN BALLINGER: The reading done on somewhere says that temperature was identified as a key variable, big source of uncertainty, major source of uncertainty.

MR. WOOD: Certainly, you can fine tune the model. I was just saying that temperature will be correlated with dose because it's a decay heat, and that's where your dose is coming from, so there is a correlation there. You can certainly fine tune it and try to do that. I think the temperature, they use the temperatures to try to, you know, they get the buoyancy factor adjusting your B- I shouldn't say B-

CHAIRMAN BALLINGER: More related to

RACKLIFE.

MR. WOOD: It's a RACKLIFE issue. It's like a RACKLIFE prediction, that we're trying to use B- but add temperature predictions into RACKLIFE and, you know, nobody had looked at it and seen exactly B- we didn't know exactly what they were doing, so when they were questioned, the licensee was questioned on that on a 50.59 basis, they stepped back to the old method, so we really haven't had a chance to look at the new RACKLIFE model that used temperature.

CHAIRMAN BALLINGER: Okay. We're behind and I don't know how long Scott's presentation is going to take, but can I propose that we have the break here and then pick that up? You've donated some time. Right?

MR. YODER: Well, my presentation should be pretty quick. It's all information that we're requesting in Appendix A which everyone should have already seen so basically I'll field questions anyone has on what we're asking, and I'll rip through that presentation. Should make some time up there.

CHAIRMAN BALLINGER: Okay. So, let's take a break until 10:28. How is that, 15 minutes, please.

(Whereupon, the above-entitled matter went off the record at 10:12 a.m., and resumed at 10:28 a.m.)

CHAIRMAN BALLINGER: Okay. We're back in session here. We're going to B- with the translation and things like that it's going to go a little bit more deliberate, so let's be sure that we're B- if you sk questions, there's going to be a little time delay here.

MR. KREPEL (through interpreter): Thank you very much, I appreciate you clarifying that, Dr. Ballinger.

All right. My name is Scott Krepel. I work with Kent Wood and Spent Fuel Team, and today I would like to start by presenting some information, background here for the regulatory content, and with operating experience information. As Dr. Pulvirenti and Mr. Wood previously discussed, the technical background included with the criticality analysis and the degradation for the neutron absorbing materials. Now I would like to discuss how the NRC and the licensees have been working together to resolve these issues in the past until today.

And as Kent Wood discussed, the regulatory criteria for the subcriticality mostly is in 10 CFR 50.68, the general design criteria there. I won't discuss that again today because Mr. Wood has already discussed that, but I just wanted to remind you that's where the information is from, and there will be a few

other requirements equivalents there, as well.

And the licensees have submitted the criticality safety analysis. They can demonstrate that they meet this criteria, so the licensees can't credit for the neutron absorbing materials. So, therefore, if the licensees are able to demonstrate compliance with the requirement, then the neutron absorbing materials must demonstrate that they can continue the functionality as described in the criticality analysis. So, the neutron absorbing material degradations is safety and regulatory compliance issue.

And Dr. Rempe has asked a question previously about the operating experience that we have with degradation, and there's a lot of that experience listed in here in the information notice. So, they're briefly discussed, but you can get more information from reading the information notices themselves. They are publicly available.

MEMBER REMPE: We did read the information notices that were provided to us. Are those the only cases where licensees were outside of the limits that was discussed at the beginning, outside the bounds that was B- for their criticality analysis? Are those the ones that are B-

MR. WOOD: Probably not.

MEMBER REMPE: Okay. I would like that list of the ones that are outside. Thank you.

MR. KREPEL: All right. And in the 1970s, Boraflex was the first neutron absorber material available that showed significant degradation. And in the '80s there were some facilities that showed a lot of significant degradation, that the NRC and industry have been studying this issue since then. And we would like to note that the NRC has provided the information notices listed here behind me. I don't have to repeat the numbers again there, but in general these described different situations where the licensee identified gaps or significant degradation in the Boraflex panels.

And also there were some findings by EPRI report that have also studied this. And the NRC has concentrated efforts toward this Boraflex degradation, and have compiled them into this Generic Letter 96-04, which basically asked the licensees to provide the information that is B- that they have on degradation at this point, their performance evaluations, and any further actions that they plan to take.

And, in effect, this Generic Letter has been sent out so that it's requesting them to address the potential for the degradation in any Boraflex

credits for the criticality safety.

So, this here is Boron. In the '80s there were some issues identified with the bulging of the Boral panels, and it's discussed in Information Notice 83-29. And at that time, they were going to do something like venting B- set up some venting to relieve the pressure that has been built up in the panels. And it happened that the Boral panels had bulging and blistering continually evident there, so it discussed that more recently in Information Notice 9-26. And so far, most of the operating experience has suggested that the Boral is B- has a significant different loss in the neutron absorbing materials. And it still shows that it has blistering and bulging in the water, and the water is being displaced. And that causes significant criticality issue, safety issue because of the impact on the neutron spectrum.

A lot of this can be captured by the criticality safety analysis or by a monitoring program.

MR. WOOD: I need to stop there. I think there was a miss in the translation. We haven't seen large amounts B- we haven't seen loss of the material in the Boral. We've seen the blistering, but we've not seen the actual loss of B-10 material to this time.

MR. KREPEL: Thank you.

MEMBER SCHULTZ: So, the record I think also said that there was a degradation, therefore, in the attenuation of neutrons that it doesn't B- from what you just said it doesn't follow necessarily.

MR. WOOD: What is occurring B- I've said is the blisters form and there's a gas bubble in there, so you're changing the spectrum that is seen by the poison. It's becoming a harder spectrum because there's not as much thermalization, like you're taking away, you know, a quarter of an inch, or not a quarter of an inch, but a tenth of an inch, or whatever it is, of attenuation so you're getting a gas bubble there. So, essentially, what you're doing is you're changing the neutron spectrum that the material is seeing. It's becoming less effective in absorbing thermal neutrons, so that's the effect on the neutron absorbing B- the material is still there, it's just a little bit less effective.

MEMBER SCHULTZ: That's the way I would characterize it, a little bit less effective.

MR. WOOD: At this point, yes.

MEMBER REMPE: Remind me, has it been significant enough that you see flow blockage?

MR. WOOD: Flow blockage?

MEMBER REMPE: From the bubbles forming,

that it's basically blocking cooling flow?

MR. WOOD: We've not seen that it's B- you know, the block B- I don't think we've seen flow blockage because the water can go through the assemblies themselves. We have seen fuel assemblies that have become stuck in place and couldn't be removed, and others with a blockage that was such that you couldn't put fuel assemblies into cells.

MEMBER REMPE: Okay.

MR. CUMMINGS: I wanted to B- Kris Cummings, NEI. I wanted to make a point here that we do not believe the blistering is what has caused the bulging. In the early designs of the racks they were seal welded around the neutron absorber, the sheathing was, so it was B- those welds allow B- leaked, basically, and water got in and built up gas within the sheathing that then caused a significant bulge of the sheathing in the rack which caused the sticking of the fuel assemblies in the racks.

What we have not seen is the bulging in these racks with the tack weld which allows any gas to escape, the actual blistering to cause stuck fuel assemblies. We have not seen evidence of that in our operational experience.

MR. KREPEL: All right, I'll move on. So,

here we are with carborundum. And it has been identified that there are some concerns there with carborundum. It's in the Information Notice 09-26, and in the past carborundum has not really been monitored very closely for probable loss of neutron absorbing materials. But in the Information Notice, the licensee identified some bulging and paid closer attention to the loss there of the neutron absorbing materials. And after this Research, as Dr. Pulvirenti said, that some work has been done to research the carborundum degradation. And it has been documented there in the technical letter report.

MEMBER SCHULTZ: Why is that differentiated from an Information Notice? Why wasn't an Information Notice issued on carborundum?

MR. WOOD: On the technical letter report? We put out the Information Notice, so the annex here is there's Information Notice out here discusses carborundum degradation. We did a technical letter report to better inform us on the degradation mechanisms and what we would expect, and what we anticipate is going on.

MR. YODER: Matt Yoder, NRR. The purpose of an Information Notice is to inform licensees of operating experience.

MEMBER SCHULTZ: I understand.

MR. YODER: So, it was issued for the plant-specific experience where we had degradation of carborundum. A technical letter report was performed by our Office of Research to dig deeper into the topic, try to understand what exactly is going on, and what is the severity and the implications of the degradation so that we could make a regulatory decision.

MEMBER SCHULTZ: So, what is mentioned here as monitoring qualification programs, was that a survey of what is being done, or was that a recommendation of what should be done?

MR. WOOD: I believe what it was B- you know, part of what the user need to research is to evaluate monitoring programs and recommend or evaluate appropriate monitoring programs for the materials. I think that's what we're talking about, is like what would be an appropriate monitoring program for carborundum after they've done an analysis of what the degradation mechanisms might be.

MEMBER SCHULTZ: Thank you.

MR. KREPEL: Okay. All right, so now we have a discussion on the issues that the NRC has monitored B- with the monitoring of the neutron absorbing materials. And we've identified the monitoring

programs themselves that previously Boraflex been known to have problems with degradation since the beginning, and the licensees set out monitoring programs, or they referred to the credit that they had in their criticality analysis. And recently, the NRC has put out Information Notice 12-13 which discusses some of the recent operating experience where the NRC looked at licensees that have and did not use conservatism, and that did not apply the results appropriately to verify the continued regulation compliance.

And there are two reports published after that by the Office of Nuclear Regulatory Research that analyzed the B- excuse me, assessed the tools, RACKLIFE and BADGER, which Dr. Pulvirenti also discussed previously. So, there was some uncertainty there that identified that they would need to be B- that would be adequate to address the licensee's monitoring programs.

And I want to remind you then that Dr. Pulvirenti discussed RACKLIFE specifically with Boraflex, and its own degradation mechanism. However, BADGER, in theory could use different neutron absorbing materials to verify its neutron absorbing ability.

In recent times, the NRC has more of a

challenge for the subcriticality margin because we have new fuel designs. Licensees are getting license renewals, and other reasons that cause subcriticality margins to decrease. And we've identified there are different problems with the neutron absorbing materials that need to be monitored by these programs. So, we feel that they need to provide more guidance related to the neutron absorbing material management. And the first thing that we did was we put out a Generic Aging Lessons Learned report that discusses using the guidance for the license renewals for review. And it includes some description of the NRC's adequate monitoring programs for both Boraflex management programs, and other neutron absorbing materials.

So, the Staff guidance there for the criticality analysis also includes a statement that says that the reviewers need to think about or consider the materials models in the criticality analysis to make sure that they're consistent with the state of knowledge for the materials and by which they can verify them.

My last slide here is about the license amendment requests, tend to include a strong monitoring program, a need to look at that and be accepted and approved. And we have engagement with the industry on

this issue through different forums like the Regulatory Information Conference, and the Neutron Absorbing Users Group, and also by EPRI, and also several public meetings, for example, the working group established by NEI on criticality analysis guidance. However, we still have safety concerns related with multiple licensees that have not been able to show compliance in the last five years. And, currently, we don't use the monitoring methods that have been formerly reviewed by NRC. Therefore, we decided to go forward with issuing a general letter to collect that information that we believe will be necessary to confirm their compliance. And this information request will be discussed in the next presentation by Mr. Matt Yoder. Any questions before I turn it over to him?

CONSULTANT SHACK: The industry's preferred plan of action, at least as I understand it from the drafts I've been looking at is to go ahead with a Reg Guide to sort of formalize the guidance that you do expect, but you've somehow decided to go to a Generic Letter first. And I assume that you might come up with a Reg Guide later, but B- I mean, I'm not up B- I mean, you have draft guidance now, and there seems to be some agreement that new guidance is necessary. Why Generic Letter rather than going ahead with a Reg

Guide?

MR. WOOD: The Reg Guide is to be part of endorsing a document, an overall document that addresses more than just neutron absorbing materials. It's how to do B- form the criticality analysis. And that's currently under review as part of B- you know, it's been submitted to us and we're reviewing that. The other reason why we're going out with the B- you know, we're pushing for a Reg Guide, a Generic Letter now is that, you know, it would be B- we've had issues with licensees in the past. We feel like, you know, we need to get an idea of where people are today as opposed to where they B- you know, like a Reg Guide, if you did something like that, that might get us where we want to be in five or six years down the road, but it doesn't tell us where we are today.

MR. YODER: Let me add to that. I'm not sure that would even get us where we need to be five or six years down the road. We've got Regulatory Guides that are 10, 15, 20 years old that have never been B- or that have been adopted by only a small subset of utilities. We've got a broad question here, and we want to get an answer from all licensees. A Reg Guide wouldn't get it done. Right? That would be a voluntary application of that Regulatory Guide, so we want to go out and get an

answer from each licensee and know where they stand.

MEMBER SCHULTZ: Does the Regulatory Guide provide detailed review guidance associated with the issue that we're describing today? You mentioned it focuses on criticality analyses, but in describing how that ought to be performed and the review that needs to be done, I presume given this issue is decades old that it focuses on exactly what ought to be done with regard to degradation.

MR. YODER: Regulatory Guide doesn't exist, first of all.

MEMBER SCHULTZ: I heard it was B- I thought you mentioned it was being reviewed.

MR. YODER: There's an NEI guidance document which the plan ultimately would be to endorse that via a Reg Guide.

MEMBER SCHULTZ: Well, my question still holds, though. So, this is not a document that has been prepared, but has been outlined between B- in these discussions between industry and NRC?

MR. WOOD: No, we have B- they submitted it for review, we're currently reviewing it.

MEMBER SCHULTZ: So, I want to know what it B- whether it goes into detail associated with this issue that we're discussing today?

MR. WOOD: I'm not sure that it goes into sufficient B- you know, it mentions the monitoring program. I wouldn't make a call right now whether or not it goes into the level of B-

MEMBER SCHULTZ: It has one sentence.

MR. WOOD: It may not B- it may be B-

MR. CUMMINGS: No, there is B- this is Kris Cummings from NEI. The NEI 12-16 Revision 1 which was provided to the NRC in March based on the series of four public meetings that we had between the industry and the NRC does detail a neutron absorber monitoring program, be it either in situ testing or coupon testing. I don't say in detail. Now, we're more than willing to entertain additional discussions with the NRC about the level of detail that's provided in that document, and whether more needs to be put into it, but we have put something in front of the NRC for their endorsement.

CONSULTANT SHACK: Even the Revision O, the one sentence was just the uncertainty.

MR. CUMMINGS: I agree. Revision O did not have a tremendous amount of information in it. Revision 1 resolved that issue through the series of meetings. That was an issue that came up.

MEMBER SCHULTZ: But is it also going to get into level of detail associated with how one would

incorporate information on degradation into the analysis? I mean, that B- it doesn't seem to be a complicated process to establish in a reasonable way the application of appropriate prediction of degradation into an analysis with sufficient margin so that this is not an ongoing issue.

MR. CUMMINGS: I agree. Even at Revision 1 we did not address trying to develop a methodology for modeling degradation that we've seen associated with Boraflex and carborundum, actual loss of B-10. That was not something that we decided we wanted to try to take on because as I'll say in my slides, we largely addressed the issue.

The issue with blistering at this point doesn't seem to be something that's particularly difficult to model. You can model blisters, you can put voids in there, so I don't see that there's B- there's nothing in the current guidance document that addresses that, but we could certainly add something to try to address how do you model blistering. But there have been approaches that have been taken by individual licensees to conservatively model the blistering and incorporate it into their analysis.

CHAIRMAN BALLINGER: Okay, moving on.

MR. YODER: Okay. I'm Matt Yoder. I'm a

Senior Chemical Engineer in the NRR Division of Engineering.

As I said, we should be able to make up a little bit of time here. This is going to be a presentation of the information that the Staff is requesting of licensees in the proposed Generic Letter Appendix A.

As we've said repeatedly, the purpose of the Generic Letter is to insure compliance with the licensing basis and the applicable regulations. Once we receive responses from licensees, we'll make a determination if additional regulatory action is required. Next slide.

The information is broken into five subcategories, the material properties and configuration, surveillance program methodology, surveillance program frequency, criticality analysis modeling and how that degraded material is accounted for, and design-basis event considerations.

CHAIRMAN BALLINGER: I have questions.

MR. YODER: Please.

CHAIRMAN BALLINGER: You said determine if additional regulatory action is required. You're already interacting with industry through the give and take on 12-16 and you say there's ultimately going to

be a Reg Guide. Right?

MR. YODER: That is the plan.

CHAIRMAN BALLINGER: So, that is additional regulatory action.

MR. YODER: However, if a potential safety issue is identified through this Generic Letter process and responses, the Staff may find it necessary to take regulatory action in those cases.

CHAIRMAN BALLINGER: Okay.

MEMBER REMPE: So, I have a question, too. Again, maybe this is just my impression of how this analysis is done and the inspections are done, but with all the uncertainty we're hearing about today where the uncertainty is even uncertain, what could they possibly give you that would help you determine that they're in compliance with the current licensing and design basis?

CHAIRMAN BALLINGER: That they already haven't given.

MEMBER REMPE: Yes. Well, I mean, yes, but again it sounds like there's so much uncertainty. I know there's supposed to be a 95-95 and all that, but it just sounds like there's an awful lot of uncertainty. And, frankly, RACKLIFE only applies to Boraflex, so what do you do about the other materials? So, what could they possibly give you B-

MR. YODER: I'm going to describe that to you right now.

MEMBER REMPE: Okay. I read what was in the B- but it's not clear that these things was really going to give you that kind of confidence.

MS. GAVRILAS: Can I add a little bit of clarification here. What the documents that the Office of Research prepared did is identify sources of uncertainty. So, just because the source of uncertainty exists, the magnitude of uncertainty is not necessarily known. Just a bit of clarification because we heard some numbers, 40 percent associated with that, and 60 percent, or 30 percent with that.

We don't know the quantities of those B- we haven't quantified the uncertainties. We just know these sources exist, and some of them can be substantial.

MEMBER STETKAR: Could I ask you why you haven't even tried to do that?

MS. GAVRILAS: We don't have the information. It's not that we didn't try, we didn't have the information to do it.

MEMBER STETKAR: Okay.

MS. GAVRILAS: Maybe I'm not understanding your question.

MEMBER STETKAR: Well, typically, if you can identify a source of uncertainty, that means you understand enough about what's going on there that you can estimate the range of that uncertainty. And if you're saying this is a source of uncertainty but I have no idea how much uncertainty there is, how do you know it's a source of uncertainty? I mean, if you can identify B- honestly, the Staff is terrible at doing this, and the Staff needs to change the way they think. If you say this is uncertain, give people an estimate of your best state of knowledge regarding the range of that uncertainty.

MS. GAVRILAS: And that's why we try B-

MEMBER STETKAR: State of knowledge.

MS. GAVRILAS: We tried to do that in the report. Some of the sources of uncertainty that you'll see in there B- and I'm not going to defend B- I take your criticism to heart. I hear it. But what we've tried to do B- some of the sources of uncertainty, if you look B- the drift point that we talked, adjusting the amplifier gain, we don't know. It depends on how that curve looks, so it can be a factor of 100. It can be B- we just have little insight, so until we go and observe how this BADGER campaign is conducted and walk step by step through how they do the calibration, how

they adjust it, how they look at pulses as they come out of the detector to adjust the electronics, where they put the threshold, what criteria they use, all we can do is take good guesses and in some cases those guesses are staggering.

MEMBER STETKAR: Okay. Thanks.

MR. YODER: And we're going to get to specific questions about BADGER and RACKLIFE in this presentation. And let me just say now that those apply to licensees who are utilizing those methodologies. A plant that has a ton of coupons that represents their material will not ever have to worry about our questions about BADGER, or RACKLIFE, or any of those things. Okay, so it's important to recognize that, but we focused a lot today on BADGER and RACKLIFE because it's very important, and there's a lot of data associated. Many licensees are not going to be concerned with that whatsoever. Okay?

MEMBER REMPE: Well, it gives you confidence that you found a place or appropriate location that B-

MR. YODER: We got questions about that, as well.

MEMBER REMPE: Okay.

MR. YODER: So, material properties. I'm

not going to go through all these. Obviously, it's important to know what kind of material you have, when it was made, et cetera. We want to know what the current aerial density is, what you credit in your analysis, and importantly where did you start, so you have an idea of are you in a degraded state? Do you know where you started, and most of these may not. They may have a handle on what their current aerial density is, but they don't know the as-built material condition in all cases. Slide.

What is your surveillance methodology? Do you have coupons? Are you just performing a visual examination? Obviously, we don't think that would meet the bill. Are you performing in situ tests? It's important to note that the Staff has never said go out and do a BADGER test. We say perform an in situ neutron attenuation test that will tell us what's going on. Okay? If somebody were to admit the new test we would be glad to look at that.

What are you looking at? As I said, are you looking at the dimensions of the panel or the coupon? Are you looking at the neutron attenuation capability? What's your acceptance criteria for that? It's very important, you could get a number, but if you haven't established what the acceptance is going to be, and it

should be based on your criticality analysis of record, what do you really have? Are you trending that data? Are you using predictive codes?

The next two slides are going to focus on the RACKLIFE and BADGER specific questions. And, as I said, BADGER questions, and I think I'll reiterate, Scott alluded to it in his presentation. BADGER is applicable to Boraflex plants, it's applicable to Boral plants who don't have adequate coupons to perform a surveillance. It's applicable to any plant who has to do an in situ test, not just a Boraflex plant.

So, first, what is the criteria for choosing your panels? For a Boraflex plant, it's pretty straightforward, you use the RACKLIFE code and it tells you which panels you should select. If you're doing this for a Boral plant or a carborundum plant, we expect you to have a criteria, you know, is it because these panels have seen the most active discharge fuel over their life? Are they in a higher flow area, et cetera? We expect you to explain that to us. Are you trending the data over time, and as we discussed earlier today, are you retesting panels in subsequent campaigns? You can get a much better idea of what's actually going on if you're hitting a panel or two in subsequent campaigns as opposed to jumping around the pool and you don't

really have an apples to apples comparison.

And then what we spent a lot of time talking about today, how are you accounting for those sources of uncertainty in your plant-specific analysis, the deformation that April Pulvirenti talked about, the head detector misalignment. The other key thing that raises those uncertainties is the calibrations we discussed. Are you using a Boral calibration standard when you're testing Boral? Are you using a standard that is in the appropriate range for your as-built condition, or for your current aerial density condition? Is that a calibration cell that you brought with you? Are you using a panel that's in the pool? Are you using the same panel every time on different campaigns, are you using a different panel? These are all questions that we want to know the answer to. We think that that can contribute to that uncertainty number. Slide, please.

Regarding RACKLIFE, and as I said, this is even a small subset of plants that these questions apply to; however, we believe that there's a large uncertainty associated with this. What version of the actual code are you using? How often are you running this code, so if you're performing an in situ surveillance once every five years, how often are you

running the RACKLIFE code? Are you running it every six month, are you running it annually? And it's going to make a difference on what your prediction shows, and what cells you believe are degraded and how degraded you believe those cells are.

Obviously, describe the confirmatory testing, so the in situ testing, the BADGER testing. How does it compare to your RACKLIFE predictions? How close are you? Do you have any confidence in your current RACKLIFE model? And then describe the actual calculation for your plant, and this gets into the escape coefficient, the silica release. Are you doing a panel by panel calculation, or are you calculating the average over the whole pool? We had some discussion about that earlier.

And then as I said on the earlier slide, one of the important material properties is where are you starting from? If you have a number now for an aerial density and you don't have any reference from the past, you don't know where you are. So it's important to understand that, as well.

The frequency of your surveillance. The Staff has some guidance in license renewal space for various materials on what we feel is an acceptable minimum frequency for surveillances. Those are based

on the material type, so for materials that have not exhibited loss of neutron attenuation, materials like Boral, Metamic, the newer materials, the mixed metal composite materials, we feel that it's appropriate to at least once every 10 years go in and either hold representative coupons or perform an in situ test to confirm your material condition. For materials that have shown active degradation, we feel you should be performing an in situ test or a coupon surveillance at a minimum of a five-year basis.

MEMBER SCHULTZ: Is this information that's been specified in the Information Notices that you referenced?

MR. YODER: I'm sorry, which information specifically?

MEMBER SCHULTZ: All of this in terms of expectations given in an Information Notice?

MR. YODER: No, the Information NoticesB-

MEMBER SCHULTZ: Inclusions.

MR. YODER: Information Notices is merely a reporting of operating experience, something that has occurred at a plant that the Staff feels needs to be communicated to the licensees, so it wouldn't address things like the B- maybe I misspoke. It may touch on deficiencies in a licensee's surveillance program.

Does that answer your question? An Information Notice on a specific licensee let's say who was mismanaging B-

MEMBER SCHULTZ: It's an iteration of expectations in an Information Notice. Usually there's an iteration of expectations, NRC expectations in the Information Notice, because you're describing what has happened, and you generally see a comparison between what has happened in a deficiency B-

CONSULTANT SHACK: So, reiteration of expectations.

MEMBER SCHULTZ: Yes, exactly. Well, I call it iteration.

CONSULTANT SHACK: Iteration sounds like you're upping the B

MR. WOOD: Actually, I want to recharacterize that. In any C   MR. YODER: It's a reiteration of expectations.

MEMBER SCHULTZ: Yes, exactly. Well, I call it iteration.

MR. YODER: Iteration sounds like you're upping the B-

MR. WOOD: Actually, I want to recharacterize that. In any B-

MEMBER SCHULTZ: A restatement.

MR. WOOD: Most of the information notices I don't think you've done it. You know, they might indicate that there was an issue with the licensee's surveillance frequency or something like that. I don't know that it would get down into the details of what we would have considered. I mean, the expecting like frequency for that, you know, it's like industry operating experience. It's our version of industry operating experience. There is an issue out there. I believe that some of these B- more of the details would be found in the GALL Report. I mean, there was B- before the B-

MEMBER SCHULTZ: Right, there's another source.

MR. WOOD: That would be the source for the details. There's a lot of different materials that are out there. We've never said that we would expect the same surveillance program for every material, you know, it certainly would be tailored to the materials. But I don't think the Information Notices have this level of detail down there. It might cite what the issue specifically was that caused them B- you know, usually the Information Notices come out of something that's publicly available that we can cite, then it's in the public domain for going out.

MEMBER STETKAR: Kent or Matt, both of you mentioned B- you mentioned GALL, you mentioned license renewal. I have GALL Rev 2 here open in front of me. I don't B- I've lost GALL Rev 1 because this is sort of not relevant any more. And I haven't had the opportunity to go back through. I think we've renewed licenses now for 73 the last count units. Have you gone back through the license renewal commitments on the Aging Management Programs? I don't know how or whether, in particular, the Aging Management Programs for Boral or any other materials in the spent fuel pool, whether they changed between GALL Rev 1 and GALL Rev 2 because I don't have Rev 1 in front of me to compare. I know what Rev 2 says.

Have you looked at what the Aging Management Programs have committed to in those 73 approved license renewals in terms of is it a one-time inspection, or is it a periodic inspection according to what Matt hoped people will do?

MR. YODER: GALL Rev 1 had a program for Boraflex.

MEMBER STETKAR: Period.

MR. YODER: GALL Rev 2 has a program for Boraflex, and a program for everything else.

MEMBER STETKAR: Okay.

MR. YODER: Okay? Did we go back and look at license renewal commitments? Yes, that was part of the research, putting together the database of okay, what do we have on the docket from all the licensees that forms our knowledge base for where people are now? So, yes, we have gone back and looked.

MEMBER STETKAR: Okay. Now, the vast majority of those 73 plants only committed to GALL Rev 1 because B-

MR. YODER: Obviously, and so anyone who didn't have Boraflex when they went through license renewal B-

MEMBER STETKAR: Right. Got it. Okay. Thanks, Matt. That's B- I know you've got to keep on schedule.

MR. YODER: We can move on to the criticality analysis. These are all questions that we've asked. How are the observers modeled in the analysis? How does your surveillance program inform the analysis? How are the uncertainties accounted for? How is the degradation or potential degradation accounted for in the analysis? Next.

We want to know what your technical basis is for a design basis event. We saw some slides earlier where you've seen material that's got gaps, cracks,

scalloping, it's embrittled. What confidence do you have that that stuff is not going to sluff off and sink below the top of the active fuel in an earthquake scenario? Next slide.

So, to wrap this up, the Staff is not requiring new analysis programs or research from licensees. We feel this is all information that should be maintained in licensee's records. We're requesting this information to determine current compliance of licensees.

As I said earlier, when we receive those responses we'll make a determination on whether additional regulatory action is necessary on a plant-specific basis, or generically if need be. So, I open it to questions.

MEMBER RICCARDELLA: What's the time frame on the responses, 90 days?

CHAIRMAN BALLINGER: I think it was 90 days.

MR. WOOD: I think we're extending that to 120 days for the final.

MR. KREPEL: I think now it's time for NEI to give their presentation.

CHAIRMAN BALLINGER: Oh, okay, there was an additional thing on the slide set.

MR. CUMMINGS: That's coming after.

CHAIRMAN BALLINGER: Oh, okay.

(Off record comments)

MR. CUMMINGS: Great. Thank you very much. I thank the NRC for inviting me here to provide the industry's perspective on neutron absorber degradation. I want to thank the members of the industry who have come here today. EPRI obviously, they've done a significant amount of work on neutron absorbers, RACKLIFE, BADGER, and then we also have I know several members of the industry from the utilities on the phone, so we have those there also.

The couple of things I want to try to leave you with today is the distinct differences in the materials that exist between the non-metallic, the Boraflex, carborundum versus what I call the metallic absorbers, which includes Boral, Metamic, Boralcan, any of these aluminum-based. I'm not going to talk much about borated stainless steel because there's really only one instance of that in the U.S., so I'm not going to touch on that.

And then the other thing I want to leave you with is the amount of work and what the industry is doing not only in the past, but also currently, and the things that we have planned for the future. So, to go on to that, next slide, and if you can go to the next

one, too.

This is just kind of a rough pictogram of the types of neutron absorbers in use. I don't provide any numbers here because this was based on a survey that NEI did that included about a 70 percent response rate. The point that I want to make out here in the two figures is the difference between the installed neutron absorber and the credited neutron absorber.

We've talked a lot about Boraflex during the first part of this meeting here. What I want to point out is that I believe in our survey we had 28 licensees indicate that they had had Boraflex in their spent fuel pool. What they said was only seven of them credited it. Of those seven, I know of at least two of those that have already undergone license amendments with the NRC to either install inserts, credit limited amounts of Boraflex which were approved by the NRC. So, we've really been proactive as an industry of trying to eliminate the credit of Boraflex, which is the big culprit here of degradation of neutron absorbers. And this also gives you an idea of kind of the percentages or the representative, you know, Boral has been used extensively for 15 years. Now you have a lot of the Metamics and Boralcans, the fully dense metal matrix materials coming in. Next slide.

So, I'm just going to touch on these very, very briefly. Really, we know Boraflex degrades. It's a radiation induced, and then it's exasperated by flow of water. Nobody denies that this occurs, but it needs to be monitored. There needs to be a monitoring program, and we agree with the NRC on this point with Boraflex. Next slide.

MEMBER SCHULTZ: And you said there's about a half a dozen licensed pools that are B-

MR. CUMMINGS: I'd say there's maybe about half a dozen that have Boraflex crediting it. They have monitoring programs or they have a reduced amount of credit. For instance, Grand Gulf was just approved with a limited about of Boraflex credit, and that was just approved within I think the last year. So, there is, you know, some plants out there with B-

MEMBER SCHULTZ: Of those six then some have already submitted information.

MR. CUMMINGS: Correct.

MEMBER SCHULTZ: And got an approval to gain partial credit versus the full credit that would have been utilized in the first place.

MR. CUMMINGS: Correct. And some of those six have also gone into the NRC with license amendment requests to remove credit and install inserts.

MEMBER SCHULTZ: And are awaiting approval of that.

MR. CUMMINGS: Yes, exactly. That's correct. Next slide.

Carborundum, Tetrabor. This was one that I did not have a sample of the material to bring. It's a hard polymer type of material. There are two types, there's a plate type and a sheet type. The difference there is that the plate type was very black. It was an order of magnitude more in aerial density and the significance there is, of course, it makes it really hard to do a neutron attenuation measurement with a really black material. And there's been some past experience with trying to do those measurements, indicating that there's a significant amount of degradation, and now with some of the SuperBADGER results they're going back and finding well, that degradation wasn't as bad as it was. Simply because there was B- we've talked about the uncertainties on BADGER, those uncertainties were so bad and are exasperated under a really heavily black neutron absorber that basically made those old results practically worthless.

There are aging degradation issues, loss of weight, off-gassing from the pool water exposure.

Again, we're aware of those, but this is a relatively limited number of plants that have that. I believe that was in April Pulvrenti's report. There's four, maybe five plants that still have this. They credit it, and they all credit some reduced amount of that material.

MEMBER SCHULTZ: So, the better the absorber is, the worse B- the more uncertainty you have with the BADGER measurements.

MR. CUMMINGS: Yes, simply because you need a higher count rate. Your count rate would go down with a much heavily absorbed material. Next slide.

Boral, it's aluminum boride carbide cermet. Again, the aging issues are primarily blistering and then some small localized pitting. We have seen no observed loss or redistribution of the B4C. There's no identified mechanism that would actually lead to the loss of B- and when I say that, significant loss. Certainly, if you have a pit it could go through the aluminum cladding, you could have a very localized, smaller than a millimeter in diameter loss of some B4C. You could around the edges have some small losses of the material, but we haven't seen the type of degradation that we've seen in carborundum or Boraflex in this type of material.

EPRI has a Boral database that contains

data extending over 25 years and we have 35 years of pool operating experience with this material, and 50 to 60 years of experience with this material in other situations.

MEMBER SKILLMAN: So, Kris, what you said earlier was that there may be some physical deformation related to Boral which would make a cell unuseable or difficult to use, but that would not affect its neutron absorption characteristics.

MR. CUMMINGS: That's correct, it would not affect its neutron absorption capability or its efficacy.

One other point that I wanted to make here is the blistering is B- there have been several different manufacturing processes with Boral. Some of the early, the powder was mixed with oil, and then it was sandwiched between the aluminum and rolled. It was different than the actual rolling process. And that's led to different amounts of porosity in the material which is really what's leading to the blistering, that the water gets in through the pores and then it gets trapped there, and then the gas has no place to go so it causes the blister.

There's coupons that we have, that we brought them out after 20 years, there's no blisters

on them. There's other ones like you see in this picture where they have a dozen to two dozen blisters primarily around the edges. And from the evidence that we've seen at some of the plants they do grow with some size, but other plants have seen them grow and then stop to grow. And that's been simply putting them in, taking them out. They don't do anything to the coupon, they don't dry them because that would exasperate the blisters. Next slide.

The metal matrix composites are the new ones. They're fully dense. There's little to no porosity, I believe it's less than half a percent. The expected aging issues would be pitting and generalized corrosion as would be expected. Because there's no aluminum clad, there would be no blistering possible. And we haven't seen any loss or redistribution of the B4C. And we've got about 10 years in service with these types of materials. Next slide.

So, for carborundum and Tetrabor in our survey all the plants that responded indicated that they did have monitoring programs in place for them. For Boraflex, as I indicated on my first slide, the majority of the plants have discontinued credit, and the remainder are really looking at regulatory approval for modification to their spent fuel pool to eliminate

the credit and put in inserts.

For Boral, there we have an instance where about 50 of the plants do not have a coupon monitoring program, but they do monitor the industry through the EPRI Neutron Absorber Users Group. They obviously get OE through INPO, so they continue to monitor the situation with Boral to see if there was actually loss of B4C and then they would evaluate that in their plants.

Metamic and Boralcan, they all have coupon monitoring programs because those are pretty much newer applications. Next slide.

So, now I want to get into the neutron absorber testing. A lot of this is what's in NEI 12-16. The purpose is really to be able to understand that we are not undergoing anticipated aging effects that would impact reactivity, that any aging effects would be observed in the coupons in advance of the expected degradation in the racks. To your point, Joy, about where do they place them? They place them in areas where the freshly discharged fuel is placed. With the non-metal matrix materials that was typically to try to get as much irradiation on those materials as possible, so certainly with Boraflex, a lot of those coupons are not there any more because they were

irradiated more than the majority of the racks.

MEMBER REMPE: The irradiation effects will play the temperature effects, but isn't there a flow effect also?

MR. CUMMINGS: There is a flow effect, so typically the coupon tree goes into an empty storage cell, so some of them are encapsulated, some are not, so there's not B- I'm not aware of whether there's been a correlation between the coupon tree and what's in service. But that's what I'll get to about what the industry is doing. And then, of course, we want to make sure that the neutron absorber is there and provides the level of reactivity control that's assumed in the analysis. Next slide.

There's really two preferred methods that we recommend in the NEI guidance document for licensees. It's coupon testing and in situ measurements. And really in situ measurements are really to either supplement coupon testing or in lieu of coupon testing if there's no coupons available. The preferred B- the number one preferred approach is coupon testing, and recent licensees that have gone into the NRC have adopted coupon testing programs. Next slide.

These are just kind of the criteria that

need to be met. I won't go through that, but if you have any questions feel free to ask me. Next slide.

Here we get into kind of how do we use the results. For coupon testing what we'd like to see is kind of an approach that is dependent upon the mechanisms that you've seen. So, for things like the metallic materials, you start with a basic testing. You pull them out, you do photography, you take measurements on them. You know, you look to see whether there's any actual visible degradation or aging mechanisms that have occurred to the materials. When you start to maybe see that, you know, whether that's decades or longer or less. Then you go to a more full testing where you're starting to have some uncertainty about is this absorber doing something beyond what we expected it to do? And then you get into, you know, the detailed B-10 aerial density measurements, microscopic analysis, possible micro structure analysis and characterization of the degradation. And you do that in addition to the basic testing. Next slide.

For in situ measurement, again we've got the B- I've got the criteria up front. One of the things here that we're really trying to point out is how do you use the results of the BADGER testing or any other in situ testing. And we've seen there's relatively

large uncertainties. And the concern that we have as an industry is that okay, you've assumed some amount in your criticality analysis, and now you go do this in situ test.

Let's say you do it five years after you've installed those racks. Well, now you've got this huge uncertainty, but you don't actually have any real evidence that that material has degraded, so trying to apply the uncertainties on a tool that we know is very uncertain and using that against your analysis of record for your criticality is not providing an accurate technical picture. So, what we're trying to illustrate here is that for material with potential performance experience which doesn't result in a loss of a neutron absorber capability, so you may have some of this pitting, you may have some of this blistering.

The measurements need to be used as confirmatory. You're confirming that your as-manufactured material is basically still there, so you basically don't have any significant degradation, so you're going in and you're taking your nominal results from your BADGER and comparing that to your criticality analysis.

For materials that do have potential performance experience like your Boraflexes, your

carborundums, where you're trying to credit something other than the as-manufactured value, now you do need to include that in there because now you're basically B- you have an uncertain situation and you're trying to come up with what is the actual aerial density of that material where you don't necessarily understand all B- everything that's going on, especially for individual panels.

MEMBER SKILLMAN: Kris, unless you have a baseline, how do you know whether or not there's been degradation?

MR. CUMMINGS: Well, that goes to one of the other questions that was asked, was you have a baseline in that you know the aerial density of your as-manufactured material. All of it is manufactured under an Appendix B quality program. They do aerial density measurements in the lab so they get measurements, and especially for the coupons, that all has to be characterized for coupons. But even on the batches of material that go into the racks, those B- they take basically coupons from those batches B-

MEMBER SKILLMAN: Well, I understand for coupons. I'm talking about in situ. You just said what you do is you take a look and see whether or not there's been degradation. I would respond, you don't know

whether you have degradation unless you have a baseline on your in situ.

MR. CUMMINGS: I think that's applicable to some of the materials that we've seen degradation, but for the materials, the metallic materials we haven't seen any evidence of degradation of these materials that would affect the neutron absorber efficacy. So, something like Boral, we have no operating experience that you've seen this loss of material, so you can rely on the as-manufactured aerial densities for comparison.

CHAIRMAN BALLINGER: So the as-manufactured is your baseline?

MR. CUMMINGS: Yes. Exactly.

MEMBER REMPE: And if you do a BADGER measurement you can confirm, but it doesn't change B- do you see 30 percent uncertainty in your experience if you did a repeat BADGER measurement or a SuperBADGER measurement, or what's the industry view of that number?

MR. CUMMINGS: There's B- I would B- from my personal perspective, I would like to see a better test, whether that's SuperBADGER, I'd like to see a better, more accurate test. However, I think fundamentally there's going to be larger uncertainties

on any in pool test than you can possibly do in the lab, simply because you're under 40 feet of water shooting neutrons through steel, neutron absorber some amount of water, so there's going to be some amount of uncertainty that's included there. What we're trying to advocate is that there's B- that we don't completely ignore the as-manufactured condition and the operating experience that we have from 35 years of experience of at least certainly Boral.

MEMBER REMPE: Well, you still haven't heard a number.

(Simultaneous speech)

MR. CUMMINGS: B- on the BADGER.

CHAIRMAN BALLINGER: No, what you're saying is if you don't observe any degradation, the fact that BADGER or whatever you're using is 40 percent uncertain has no relevance.

MR. CUMMINGS: Correct.

MEMBER SCHULTZ: But why would I perform that measurement then?

CHAIRMAN BALLINGER: Yes, that was B-

MEMBER SCHULTZ: Why would I not want to just compare what I believe my pool performance is versus a sister plant?

MR. CUMMINGS: Well, because the plants

that have gone through license renewal that haven't had a coupon measurement program have had to commit to doing an in situ test. So, they've committed to having to do that some point after their license renewal, or it may actually be prior to license B- they actually really get to their license renewal period. So, they've made a commitment to have to do that, and that's been a requirement that the NRC has imposed. So, I would agree, I don't see a lot of benefit in that, but they've committed to it, so now how do we use those results?

MEMBER STETKAR: You made a broad statement which said the plants that have gone through license renewal. Earlier I asked whether GALL Rev 1 applied to everything.

MR. CUMMINGS: Right.

MEMBER STETKAR: You B- to be precise, the plants that have gone through license renewal that have Boraflex that made that commitment, which you say is B- and a fraction of the actual plants have gone through license renewal. Is that accurate?

MR. CUMMINGS: That's accurate B-

MEMBER STETKAR: Have any plants that to do not have Boraflex who have had their license renewed committed to in situ testing?

MR. CUMMINGS: Yes.

MEMBER STETKAR: Okay.

MR. CUMMINGS: Now, there certainly is that discrepancy between GALL Rev 1 and Rev 2.

MEMBER STETKAR: And the majority of plants that have gone through license renewal have committed to only GALL Rev 1. Is that correct?

MR. CUMMINGS: Right. That's correct. Now, I can't speak to what every plant has committed to in their license renewal.

MEMBER STETKAR: And that's why I'm questioning your broad sweeping statements B-

MR. CUMMINGS: Right.

MEMBER STETKAR: B- about all the plants that have gone through license renewal are doing this in situ testing.

MR. CUMMINGS: Right.

MEMBER STETKAR: Because it's not clear to me how many of them are.

MR. CUMMINGS: That's a very good point. Thank you for pointing that out. There have been licensees that have gone through license renewal under GALL Rev 1 that have made commitments to do in situ testing B-

MEMBER STETKAR: If they have Boraflex, yes.

MR. CUMMINGS: Even with Boral.

MEMBER STETKAR: Okay.

MR. CUMMINGS: So, some of that was done under kind of site-specific aging management programs even though that wasn't in the GALL report.

MEMBER STETKAR: Yes, yes, yes. Okay. Thanks.

MR. CUMMINGS: Okay, next slide. So, is this a safety issue? And this is very similar to what I presented at the RIC. You know, from our perspective the degradation of the older neutron absorbers, specifically Boraflex and carborundum, have largely been addressed by either elimination of the credit, installation of new absorber inserts, or monitoring/re-analysis with a conservative treatment and prediction of the neutron absorber presence. And you saw that in the first slide certainly for Boraflex.

MEMBER REMPE: Well, okay. I really would like hard numbers. I heard earlier today that that list, the spreadsheet was the plants and what they're taking credit for. You mentioned only 28 of the respondees had applied, there weren't many more plants. I counted up on your list just out of curiosity, I've seen 11 plants still take credit for Boraflex, if that's indeed what the list represents, and three take credit for

carborundum. Can someone verify if that's an appropriate number or not?

DR. PULVIRENTI: This is April Pulvirenti from Research. That update was done last spring and the number has been steadily going down since we began this effort, the amount of Boraflex credit. In addition, we chose to assign credit if it was the official license amendment. And at the time, these credits can be in flux. For example, we may have a license amendment that's under review at the time that I did the spreadsheet. It may have been under review, and so I'd say it still credits Boraflex as of right now, even if something is under review. We have a couple of instances where an amendment has been approved but the licensee now has to implement. For example, putting inserts in, so we think Boraflex is still being credited while that is being implemented, so there are several that are in flux, and you almost would need something up to the day. That's why you're seeing even an uncertainty even in the number that are who's officially crediting what.

MEMBER REMPE: It should be possible to answer the question what the current status of B-

(Simultaneous speech)

CHAIRMAN BALLINGER: It runs to the crux of the issue on Boraflex. Does that trend to zero? In other

words, is it the industry's trajectory to eventually eliminate the problem of Boraflex by just getting rid of the credit all together?

DR. PULVIRENTI: That's an industry question.

CHAIRMAN BALLINGER: That is the trend.

MR. YODER: This is Matt Yoder. Let me chime in here. Yes, there's uncertainty between what's reported in our database, what's been reported by NEI. And correct me if I'm wrong, how many respondees were there to the survey? It wasn't the entire B-

MR. CUMMINGS: It was 70 percent.

MR. YODER: Okay, so there's uncertainty there. We don't know exactly. That's why we're asking the question in the Generic Letter, what is your material at your plant?

MEMBER REMPE: Okay.

MR. WOOD: And as far as I know, the trend isn't to zero, because there's the one for Grand Gulf that we just approved that is going to go in perpetuity for Boraflex credit at this point. You know, I know of no plans B-

(Simultaneous speech)

MEMBER REMPE: Right.

MR. CUMMINGS: But they have a monitoring

program in place. They've committed to that. They've got an amount assumed in their analysis, so they will continue to evaluate the efficacy of their Boraflex against what they've assumed in their analysis.

CHAIRMAN BALLINGER: And, presumably, that was part of the licensing B-

MEMBER SCHULTZ: For any use of Boron we have a license amendment request for that.

MR. CUMMINGS: So, I don't want to get too far ahead of myself, but that's a great example with Grand Gulf. Why do they need to answer to the Generic Letter when they just got approval less than a year ago, and that was approved by the NRC? So, I'll get into that, and that goes into the proposed alternative.

The aging effects for the metallic absorbers is a very slow process. It takes decades. It provides advance indication through either the coupon testing, in sit measurements, and pool chemistry observations. All of the pools have chemistry observations. That's how we initially saw Boraflex degradation was the increased silica amounts in the pools.

There's a large amount of loss of material, 50 to 60 percent is needed to overcome just the administrative margin. So, as in the NRC's

presentation, if you look at the numbers there, you need 50 percent degradation to get down to actually overcoming this administrative margin, so you've got time to be able to address these things before they become safety issues.

The last bullet I want to address really in terms of what is the reactivity effects of these various aging mechanisms? If it's pitting, generalized corrosion, localized loss of material that we've seen in some of the coupons, that has really a negligible effect on criticality. You know, a pit small than a millimeter, even smaller than an inch, that has no affect on your criticality analysis. In my previous life working for Holtec, a rack and neutron absorber manufacturer, Boraflex gapping less than an inch, you couldn't see that in your criticality analysis. And I was assuming that that gap occurs at the same location in every panel throughout the pool, so there is a level, we think, of threshold before this even has a compliance issue.

Boral blistering where you see, you know, a void being created, while theoretically that could have an affect on flux trap racks. That's these moderate density racks that the NRC has characterized. If you take the height of the blister and you make it over the

entire length of the panel, then yes, you're taking essentially water out of your flux trap. So, that's going to have an impact on your criticality. However, if you go in and actually model this realistically, the actual size and diameter of the blisters, that again because they're relatively, they're dispersed throughout the panel, that has a relatively small effect on reactivity. And again that's because they're throughout the panel distributed. And these sorts of effects will be addressed in the licensee QA program. You have blistering or you have a loss of material, you're going to evaluate that as an operability determination. You're going to look at what effect that has. You may actually go in and say do I have some margins in my analysis that I can use to offset that? That's all done not just in spent fuel pool criticality, but in other areas in the plant. There are processes in place to address these sorts of, you know, small aging effects within the context of the criticality analysis. Next slide.

It's also very important to point out there's a significant amounts of independent reactivity hold down in the pools. For BWRs you have about 2,000 ppm soluble boron. That equates to about 20 percent reactivity. That is a tech spec

requirements. For BWRs pools, the analysis itself is based on maximum reactivity. If you actually consider, you know, that most of the fuel is full burnup, it's not at 15 gigawatt days, it's at 45 or 50 gigawatt days. That provides about a 10 percent margin reactivity. You do have your administrative margin, and it's B- neither of these gets into the actual conservatisms of the analysis.

For the BWR, every plane is investigation. It's basically a 2D, and you look at the worst 2D plane. PWR, you typically assume all your assemblies are at the worst depletion parameters. There's various conservatisms in the analysis. Next slide.

CHAIRMAN BALLINGER: Okay. Now, the first B- those two slides, the top has been B- is this a safety issue? But there's no yes or no here.

MR. CUMMINGS: Right. So, I would say B- and I was asked this at the RIC, and I'll give the same answer. It depends on the material. For the metallic absorbers we don't see this as a safety issue. For the non-metallic absorbers, Boraflex and carborundum, we think it's absolutely important to have a neutron absorber monitoring program. You need to know what's going on with your absorber, and that it's still in line with your criticality safety analysis.

CHAIRMAN BALLINGER: So, it could be a safety issue.

MR. CUMMINGS: For the non-metallic absorbers, correct.

CHAIRMAN BALLINGER: Thank you.

MR. CUMMINGS: You're welcome. So, what is the industry doing? So, one of the projects that's going on with EPRI right now, it's an accelerated Boral corrosion testing. It's looking at BWR and PWR spent fuel pool conditions. I think there's 130 or 40 some odd coupons. It's a five-year test program. They're currently just about a year and a half in. Oh, I'm sorry, 192 coupons. There's encapsulated and unencapsulated to try to capture the different configurations of panels in pools, but then there's also encapsulated and unencapsulated coupons in pools. It does address the various fabrication processes that was used with Boral, and they're conducted at 195 degrees to simulate about 60 years of service life.

And the first year results we've seen have showed pitting. Some of that pitting has been in excess of what we would expect even under accelerated conditions. There were no blisters, and there was not loss of aerial density, but obviously this is an ongoing program, and we do B- we're really interested in the

five-year results.

CHAIRMAN BALLINGER: Okay. And that is sort of taken for question about the 195 degrees. The Boral, the sheathing in the aluminum, that's commercially pure aluminum? It's not an alloy?

MR. CUMMINGS: I don't know the answer of what the alloy of aluminum is used.

MR. WOOD: It is an alloy.

CHAIRMAN BALLINGER: Okay. If it's an alloy, then 195 degrees Fahrenheit will age that alloy. So, that would be B- there won't be micro B- there will be changes in the micro structure during the aging, so using an increased temperature may or may not be an appropriate accelerating factor. I'm sure somebody has considered that. I just don't know the answer to that question. And if that involves precipitation of stuff in the material which if it's a 6061 or something like that, that's definitely going to affect the corrosion.

MR. CUMMINGS: Okay, great.

CHAIRMAN BALLINGER: But, again, it may be already considered.

MR. CUMMINGS: Hatice, did you want to add anything to that? Come to the microphone.

CHAIRMAN BALLINGER: It's 1,100, okay. So, that's commercially pure. Okay.

MR. CUMMINGS: Yes.

CHAIRMAN BALLINGER: That's different. Okay.

MR. CUMMINGS: So that was Hatice Akkurt from EPRI.

CHAIRMAN BALLINGER: Okay.

MR. CUMMINGS: So, she's in charge of the program.

CHAIRMAN BALLINGER: All right. So, it is not an alloy.

MR. CUMMINGS: Right.

CHAIRMAN BALLINGER: Okay.

MEMBER SKILLMAN: Kris, in this slide you communicate B- the slide communicates it's BWR and PWR spent fuel pool conditions. Nowhere on this slide is there any indication that there is either gamma or neutron flux.

MR. CUMMINGS: No, it does not include irradiation conditions.

MEMBER SKILLMAN: So, this is really not spent fuel pool conditions. This is temperature conditions plus chemistry.

MR. CUMMINGS: That's correct, it is. And part of that decision was based on EPRI's done previous work where they've shown that irradiation is really not

the mechanism that's causing the degradation.

MEMBER SKILLMAN: For Boral.

MR. CUMMINGS: For Boral, and I don't know that I would expect that for the other metallic-based materials. You're not likely to be getting into the neutron or gamma dose rates that would get you into material degradation issues like you have for maybe PWR vessel embrittlement. You don't have that level of basically flux in a spent fuel pool.

MEMBER REMPE: Does flow affect it?

MR. CUMMINGS: I don't believe flow affects it. This is just B-

MEMBER REMPE: Temperature.

MEMBER SKILLMAN: I guess I'm not as confident as you are. PWR fresh assembly coming out 250-300,000 R per hour, put that three inches away from the next one.

MR. CUMMINGS: Right.

MEMBER SKILLMAN: That is a huge flux.

MR. CUMMINGS: Okay.

MEMBER SKILLMAN: That is a huge gamma flux.

MR. CUMMINGS: Okay.

MEMBER SKILLMAN: There's a good neutron flux that goes with it. So, it seems to me that one might challenge the, if you will, the applicability of this

test to what one might postulate is actual condition inside a wide pool.

MR. CUMMINGS: Right. Yes, I agree. There are certainly some differences from what you would see in the pool basically because you're doing this in a lab versus doing this is an actual spent fuel pool.

MEMBER SKILLMAN: I can understand the temperature, and I can understand chemistry, but I'm just asserting irradiation is very much a part of what's happening in the pool, and this doesn't represent it.

MR. CUMMINGS: No, I agree. Yes, we B- that is understood going into this program.

CHAIRMAN BALLINGER: So, EPRI programs have verified that there's no radiolysis effect.

MR. CUMMINGS: Yes, there's B- one of the reports I gave you, I believe they stress a list of reports that EPRI has done, 30 reports over the last I think 20 years. One of those addressed that issue. I can certainly take that as an action to identify which one that is.

MEMBER REMPE: And have it sent to us, if you don't mind.

MR. CUMMINGS: If I can. I'm not sure if it's a proprietary or not.

MEMBER REMPE: I'm not sure we actually got

the B-

MR. CUMMINGS: No, you did not.

MEMBER REMPE: Okay.

MR. CUMMINGS: I provided them and asked if you wanted them, but B-

MEMBER REMPE: Okay.

MR. CUMMINGS: So, if you want them we can certainly go through the process.

MEMBER REMPE: This one would be nice to have.

MR. CUMMINGS: If it's publicly available, I can commit to providing you that. If not, I have to talk to EPRI.

MEMBER REMPE: Yes, sometimes your reports cost, and so that's why I didn't buy B-

MR. CUMMINGS: I understand, and these are not pocket change.

CHAIRMAN BALLINGER: It's always better to have more information than you need and discard it than not have it and need it.

MR. CUMMINGS: Understood. Yes. Okay, next slide. The next is April talked about this a little bit. It's a comparative analysis project at Zion. The intent here is to B- because they're decommissioning, we can B- we have access to their coupons. We have access to

their racks, and we're going to get NETCO to do some BADGER testing, so that will allow us to look at the comparison of BADGER tests to coupons, to in situ or in-service rack material which is not something that's been looked at before. So, Exelon has been very accommodating to allow the team to come in and play around in their spent fuel pool while they're trying to quickly put everything into dry cask storage, so I have to give them some kudos there. And that will B- you know, we're hoping that will provide some additional technical basis for the long-term use of Boral, because it now B- it allows us to put together the dots, so to say, between how does the coupons compare to in-service material, how does BADGER compare to in-service material? You know, I view it almost as a benchmark of the BADGER. I believe it's SuperBADGER. I use BADGER very loosely here, but it's the latest version.

MEMBER REMPE: When is this to start?

MR. CUMMINGS: Later this year is when they're going to go in, and I believe November is when I think they were going to do the BADGER. They'll take some B- they'll take the coupons, and then they'll also cut material out of the racks, and use those as coupons and send them to a lab for testing. And we'll be providing some to the NRC as they indicated.

DR. PULVIRENTI: Kris, could I clarify? This is April from Research. The BADGER testing is going to be done during the casking period in late October. The coupon removal and harvesting I believe will be late next spring, May-June, because that will be done after the casking period. The BADGER is done during the casking period to take advantage of analyzing racks that do and do not have the gamma interference, and we hope to have some resolution of that uncertainty, which is why we're doing that earlier. Thank you.

MR. CUMMINGS: Next slide. As we discussed before, there's the NEI 12-16, which includes a section on an appropriate monitoring program. We look forward to having continued discussion with the NRC on that. There is an EPRI Neutron Absorber Users Group that meets yearly where we share results, we share what we're seeing. All the utilities are members of EPRI, so they're more than welcome to come. There's usually pretty good participation at that, so even outside of the formal processes of INPO reporting and Part 21, and things like that, there's other things the industry is doing.

And then we've also started looking into whether EPRI can do some criticality analysis to determine a realistic effective postulated aging

effects and degradation on the criticality analysis. Now, this, we're not focusing it on the Boraflex or carborundum type of degradation. We're really focusing it on the metallic materials.

How big of a pit do you actually get before that's a criticality effect? I know from my past life we put one-inch holes in it, and we haven't seen an affect on criticality, so we're going to try to make sure that we cover a broad range of rack types, different neutron absorber densities. It's very similar to the sensitivity studies EPRI has already been doing to support the NEI 12-16. Next slide.

So, this is basically what we proposed to the NRC on Tuesday, which is an alternative to issuing the draft Generic Letter to all licensees. And that's basically to allow licensees to commit to an acceptable neutron monitoring program, i.e., something like in 12-16. Obviously, we'd have to come to an agreement with the NRC on what that monitoring program looks like.

We also believe that the focus of the scope of the Generic Letter should be on the susceptible material, such as Boraflex, and carborundum, and Tetrabor. That's in line with using a risk-informed approach to focus on the things that we think of most concern.

And we think there's a good case to be made for excluding some of the licensees from needing to respond. One of those would be that they don't credit an absorber in their criticality analysis, maybe they had Boraflex, but they've already gone in with the NRC and gotten approval for not crediting that. Well, then they're not going to have an absorber program. There's really no need for them to have to reply to the letter. Now, I don't think that letter is difficult or time consuming for those individual licensees to respond to, but there's not much value in that.

Second, licensees that have undergone license renewal and have an existing aging management program, maybe there's some nuances there, John, that we could add about GALL 1 and GALL 2.

MEMBER STETKAR: You said and have existing aging management program for this issue, for their particular material.

MR. CUMMINGS: Correct. Correct. Exactly. And then the third would be if somebody has gone in in the last five years with a criticality analysis. And there the five years was kind of trying to tie in with the time that the GALL Rev 2 came out, because that defined an absorber program, or the need for one. And that was about the time that more attention was being

paid on this. So, again, the five is a recommendation.

MEMBER STETKAR: Yes, that's kind of a fuzzy five.

MR. CUMMINGS: It is a fuzzy five. Right. Exactly. It's less fuzzy than recent, so B- and then, finally, for the remainder of the plants we would like to see the detailed information in Appendix A removed, or the request for that. And that really gets to when we look at the Generic Letter, the meat of the Generic Letter, there's five things that are asked for that was in that.

We think licensees can respond to that in the time frames that the NRC has provided. And it also provides some flexibility to the licensees on how to respond to that. If there's this Appendix A which is five pages of detailed information, a licensee is going to have to respond under oath and affirmation to each of those individual bullets. And working in a plant, sometimes it's harder to prove that you don't have something, and it's more effort to prove that you don't have something than it is to say, you know, I use RACKLIFE Version XYZ. Well, that should be relatively easy to do.

There's some of those instances of that material in Appendix A that may be very problematic or

time consuming. I don't want to say problematic, time consuming for a licensee to provide under oath and affirmation. And we think the meat of the Generic Letter would serve the purpose for licensees to respond.

CHAIRMAN BALLINGER: What you're saying then is, in this slide you're saying we don't need a Generic Letter, but if we do, if there is one, then you differentiate between the first red dash and the second red dash begins with assuming that the Generic Letter is issued. In other words B-

MR. CUMMINGS: Correct. Yes. Essentially, what we're saying, if you're going to issue the Generic Letter, let's focus on Boraflex and carborundum.

CHAIRMAN BALLINGER: Yes.

MR. CUMMINGS: That seems to be appropriate. And the case that I'm trying to make is that we do have information on the metallic absorbers. We're not seeing the degradation that would cause this to be a safety issue, and we're continuing to do research in the industry, and monitor through, you know, individual licensee's programs, and through the industry as a whole, so we're going to know what's happening with these absorbers as we go forward.

All right, last slide. So, in conclusion, we feel like we have B- the industry has responded to

operating experience and NRC notifications through license amendment requests, especially for the non-metallic absorbers. With 35 years of in-pool exposure, Boral continues to provide the same level of neutron absorption capability as when it was installed. You know, the newer metal matrix materials were developed in part to address the blistering issue, and we expect those to provide a similar or better level of performance.

The ongoing research and existing monitoring programs will help to provide additional information in advance of when we would expect to see any sort of aging mechanisms that might progress to the point where it would have an impact on the criticality analysis, and become either a safety or a compliance issue. And our proposed alternative we believe is a risk-informed approach that focuses industry and NRC resources on those materials that are most susceptible to aging or degradation mechanisms. So, that's the bulk of my prepared comments. I'm more than happy to entertain any other questions.

CHAIRMAN BALLINGER: Any questions from the Committee? Thank you very much.

MR. CUMMINGS: Great, thank you.

CHAIRMAN BALLINGER: May we have closing

presentation.

MR. KREPEL: Okay. All right. I'm going to skip a few slides because as you already know, the Generic Letter has been released for public comment already, so we've collected public comments. And we have been thinking about what we'd like to discuss as our general point of view, with a few specific issues that have come up in the public comments. So, some of them have been included in what Kris was discussing earlier.

And during the two months that the letter went our for public comment, we collected 11 letters. Most significant comments there were letters from NEI, and we've gotten letters from other licensees, and vendors, as well. But, in general, they were reiterating or supporting comments from NEI.

In general, it seems that the three primary areas of concern are first, about the scope of the Generic Letter itself, especially Appendix A. Secondly, the time that it took for them to respond to the General Letter, Generic Letter. And also for the issues specifically about compliance to safety. So, those are the three that we're going to discuss now.

We have information about the scope. We are not requesting new information, but specifically we

would like to have development of responses from these viewpoints. For example, we've indicated that we had information there that looked like it was open for interpretation, and we wanted to clarify again so that B- we were not requesting information that was previously not required by the NRC. And we would like to let you know that we know that the licensees are currently demonstrating compliance with the NRC, the subcriticality requirement for this purpose, so they can submit to us information that they believe they are already keeping in accordance with 10 CFR 50 Appendix B. That's a documentation requirement already.

And with regard to Appendix A, they have specific lists documenting, justifying exactly what the NRC Staff expects would be their response with the questions. And the exact nature of the response from the licensees will depend on the specific licensee because they'll have different neutron absorber materials, and material absorbing programs. So, this list is providing guidance to the licensees in response to this Generic Letter for increased B- to increase the transparency or predictability.

I think the NRC has also addressed several comments in this area, and we provided better definition for members that have requested information

for Amendment A. Any information from the Generic Letter can be provided and there will be a response in four general areas that were mentioned before. And some things may not apply, for example, if a licensee has Boral, then there's no reason for them to respond or answer the question about RACKLIFE.

Another example is if the licensee has all the information requested that's available that the NRC has already approved in the amendment request, then they can just refer to that, and just say that's in the description, and that's what they're currently doing. They can make note of that, so the Staff would be acceptable with that. If the information is already available in their records, then they can just provide it. And, finally, if it's not available, then they can just state that as such. They can just say that that information is not available. And we would recognize that in some situations that they can just give us that information regarding what the issue is, and then it can be addressed by the information that's provided.

The next category that the concern was regarding the administrative burden or the administrative responsibility that would be needed. We don't expect to have an increase of 1,000 man hours, for example, to meet the needs of this Generic Letter.

It would only be several B- we only expect maybe a few hundred man hours, so we do want to clarify that. We didn't want to put an extra burden for people to look and find additional information, but it depends upon the administrative procedures that are in place. They may have the information and we'll be B- as the NRC Staff, we can review that information and consider the time that's required. But the purpose is not to add an increase. They can B- like I said, the purpose is not to increase the man hours, just to have a few more man hours, a few man hours at that point.

We do believe that it is within the scope of Amendment B, and it reflects B- in the past, we've had several comments that come in and it's taken a long time to respond to those in the past, like in 96-04, for example, was related to Boraflex monitoring program. And as well, in 08-01 was related to gas build up that was in the liquid injecting system. Right now, those two General Letters, the requirements rather for those two Generic Letters require B- doesn't require a new monitoring program. So, we're just basically requesting information and the time requirement will be a lot less to respond.

Now, in terms of relevance we're talking about here, there have been some comments that have

provided that talk about the subcriticality margin shouldn't be part of the plant licensing basis. There shouldn't be credit to address issues that weren't considered. So, when a person feels that's true, the first thing to do is to re-analyze the significance B- we basically take the conservative approach, and it's basically a conservative estimate.

MEMBER SKILLMAN: Question, please? May I ask you to please give an example of what B- a practical example of what you mean in the first bullet?

MR. KREPEL: That's a good question. A good example would be that in the previous presentation it was discussed that administrative margin there, 0.05 delta K. And that is included in the requirement for subcriticality limits. So, industry is required to meet that limit which means that they can't claim credit for the limit for another purpose. Is that made clear?

MEMBER SKILLMAN: No, almost. What would another purpose be?

MR. KREPEL: Another example for conservatism assumptions may be made by -- I believe Mr. Wood discussed this morning in his presentation, but the license for BWRs tends to analyze their most reactive license lattice as burnup where the reactivity at the maximum is more in the spent fuel pool at a higher

burnup. But it's possible to have a lower burnup fuel in the spent fuel pool, as well. So, that's not really the margin that they can claim for another purpose, like the neutron absorbing material degradation.

MEMBER SKILLMAN: I understand. Thank you. Thank you.

MR. KREPEL: My pleasure. And I should tell you also that in the past licensees have submitted updated information to their criticality analysis, and have included possible degradation of material like less than Boraflex credit, or a model of degradation. So, the licensees in the past have recognized that they have needed to accent or account for the degradation.

And the second bullet point there on the board is the one thing that the fact that there are newer metallic absorbers that haven't degraded, like Boral. Degradation has not been perceived to be significant at the plant; however, we must say that in the past up until recently the carborundum is not really considered to be problematic. But now we are concerned about it, because the point is that you can't identify degradation until you have a program to monitor for it. And that the NRC, we've seen these situations where licensees have good assumptions with their monitoring program. They're not using the results from the program

appropriately. And that shows that it's significant, and it's having a big B- it is effective to have a program.

CHAIRMAN BALLINGER: I have a question about the second bullet, though. Joy has asked, maybe some others that recent operating experience shows that effective monitoring is necessary to insure compliance. What exactly was the non-compliance? We need to B- I'd like to have the details of this. And then given that assumption, that there was some non-compliance, what's the trajectory, what did the industry do? In other words, is the issue of non-compliance going to go away because of the interactions that have taken place? We're likely to continue to have an incidence of non-compliance, in other words.

MR. WOOD: You know, I certainly can't talk off my head on every instance of non-compliance we've had.

CHAIRMAN BALLINGER: Have there been many?

MR. WOOD: Yes, sir.

CHAIRMAN BALLINGER: Oh.

MEMBER REMPE: That may be 10, 20?

MR. WOOD: Oh, about half a dozen or more. The one that started off or really got a lot of attention

was Palisades. Palisades was a carborundum plant. They had carborundum in their Region 1 pool, and they talked about that earlier. It had Boraflex in their Region 2 and then stopped crediting it. They went in, they had a requirement of a license renewal. I believe it is license renewal to do a test before they entered their period of extended operation. They went in with B- they had done no previous testing, no previous monitoring other than industry monitoring at a sister plant. So, they went in, they did the in situ measurements, they came up and they indicated that they might have up to 60 percent degradation of the neutron absorbing material.

Now, there were carborundum plates so they started out very high, but they ended up with a confirmatory action letter that did not allow them to move any fuel in their Region 1 of their spent fuel pool until we got a new criticality analysis that showed it was safe. You know, that at that time was going to prevent them from doing their next refueling outage. They were able to come in with a conservative criticality analysis that we said it needs to be simple and it needs to be conservative because we need to review it and approve it in a month based on their timeline. We were able to do that and get them a new

criticality analysis, it checkerboarded essentially their Region 1 spent fuel pool. They've since re-racked that spent fuel pool.

CHAIRMAN BALLINGER: We were up there recently, so that's why B- but we don't have time to go through B-

(Simultaneous speech)

CHAIRMAN BALLINGER: It would be nice to have like Joy has asked for the specifics, because that's a start/stop. That's not going to happen again.

MR. WOOD: You know, we've had instances, you know, you say it's not going to happen again. You know, like a couple of years later Millstone Unit 1 that has carborundum, as well, and they go in with the same tool, and they're indicating that they have degradation, as well.

CHAIRMAN BALLINGER: Okay. What I'm saying it's not going to happen in Palisades again.

MR. WOOD: No, it's not going to happen in Palisades, again. But it could happen at another plant in the industry.

CHAIRMAN BALLINGER: Okay.

MR. WOOD: I mean, that's why we went with the Generic Letter to find out what people are doing, and where they're doing it. Certainly, some people will

B- you know, somebody that's come in within the last five years might be able to answer the question very simply, you know. And we've tried to capture that in the Generic Letter, is that hey, we have your approved program. It was approved like two years ago. We haven't made any changes, we're done, you know. And we think that that would be a very short answer, and would be an acceptable answer. You know, like somebody that's had a program, you know, like several years ago, we may have an idea what they might have done by a commitment, but they change those commitments at any time. We've had licensees with commitments that when we've gone through and asked them what they were doing with their commitments to their program we found out that the coupons are in the warehouse and never made it to the pool. And that's happened several times. We had those types of issues, so we'll have good programs, we'll have not so good programs. And, you know, we really won't know who has what until we ask the question. And that's what we want to get at with the Generic Letter.

MR. YODER: Matt Yoder, NRR. Let me chime in, as well. This bullet is not just directed at past operating experience. The idea here is that it's kind of in response to comments we received about we don't have experience of degradation of Boral, let's say. Why

should we be forced to go and perform in situ testing? The point is if you don't look, if you don't have a program in place you're never going to get that operating experience. And you'll also not know the condition of your material. We don't feel that performing a surveillance once every decade is that onerous with these materials that have a good operating experience to date. We're just asking that people go in and actually test the material in their plant-specific pools.

CHAIRMAN BALLINGER: Thank you.

MR. KREPEL: Okay. So, in summary for that point, what Matt, and I, and Kent were making was that we're looking for information that would allow the NRC to verify the compliance, or continued compliance.

Again, in summary, the NRC Staff got the public comments and reviewed them, and in some situations we made some revisions of our Generic Letter to better justify some of the information that we are requesting. And we would not change the reasons behind the B- the reason behind this Generic Letter is being sent out, although we would like to identify, mitigate the degradation of the neutron absorbing materials to reduce the margins beyond what is needed. To demonstrate continued compliance with the NRC

requirements. And because the NRC has requirements set up the minimum safety standards that NRC Staff believes is necessary to preclude subcritical accidents, this Generic Letter identifies several events, and has discussed in Information Notices information about several events at licensee's facilities where their monitoring programs are found to be ineffective, and that identifies and mitigates the degradation of the neutron absorbing materials. And, therefore, the NRC is providing this Generic Letter to request information that we need from the licensees limited to the necessary confirmation B- to confirm compliance. And that's all I have.

CHAIRMAN BALLINGER: What you're saying is the references to the Generic Letter provide the answers that Joy and we're looking for? I didn't get that, but that's what I thought I heard.

MR. WOOD: Well, I'm not sure that the B- you know, like Dr. Rempe asked the question earlier about how many. And she asked if the Information Notices represented every single one, and I responded that no, I do not think so. So, when we put out a Generic Letter, I'm sorry, an Information Notice, we're not necessarily waiting to capture every one. Things may have come up

since. You know, there's a B- you know, it's enough of a B- you know, we wait until we get enough of an Information Notice, enough instances of something occurring to make it worthwhile to put out to the industry. It may not be the only time it's occurred. You know, the Information Notice, those are operating experience that we've put out to the industry, but the idea is that each licensee will take it and determine whether or not it applies to them, or how it applies to them, and take the appropriate action in their Corrective Action program. So, the Information Notices are not intended to capture every event that's happened. There may be events that happened since then, there may be events that happened before that. You know, these events aren't something that we're accurately tracking, you know, on any tote board anywhere, so we can probably go and grab that information. She's asked for it, so we'll get it as best we can.

CHAIRMAN BALLINGER: I think that's a good B- we should do that.

MEMBER REMPE: Actually, I have a list of questions that I want to go through at the end of this on the record.

CHAIRMAN BALLINGER: Okay. Well, I'm done. Thank you very much. Can we B- is the bridge line open?

I can't tell whether there's anybody out there.

PARTICIPANT: The bridge line is not open.

CHAIRMAN BALLINGER: The bridge line is not open? Okay. Is there anybody in the room that has comments that they would like to make while we're waiting for the bridge line to be opened? Hearing none.

(Off the record comment)

PARTICIPANT: It's open.

CHAIRMAN BALLINGER: Oh, the bridge line. Now I know. Is anybody out there?

DR. LANCASTER: Dale Lancaster, Nuclear Consultants.

CHAIRMAN BALLINGER: Oh, Dale, do you have any comments?

DR. LANCASTER: Yes. Okay. I think the NRC B- I think everyone agrees that the non-metallic absorbers have problems, and the NRC is B- and the industry has been both working hard to alleviate those problems. And there's a lot of questions still, and all that discussion is good and valuable. However, I think there's been a very, very weak case made by the NRC with regard to problems with metallic absorber plates. And that means that we're requesting information from plants where about B- over 80 percent of these plants do not have the absorber material of concern. And,

again, I think the case is B- the concern with the metallic absorber plates has not been well made. And the presentations seem to be constantly implying that there's a problem with all absorber plates when they're mainly talking about Boraflex.

CHAIRMAN BALLINGER: Noted. Thanks a lot. Are there any other folks out there on the line?

MR. KOSKI: This is Kevin Koski, First Energy.

MR. MABEY: This is Doug Mabey at Southern Nuclear.

MR. JONES: Robert Jones, Southern Nuclear.

MEMBER STETKAR: You don't need to identify yourself unless you have some comments.

CHAIRMAN BALLINGER: Oh, that's right. Any comments from people on the bridge line? Thank you very much. Okay, we can close the bridge line. Questions from the B- around the table? Pete?

MEMBER RICCARDELLA: No. I guess just to comment. I'd like to thank both the Staff and NEI for a very informative presentation area that even though I'm a materials guy is not exactly right down my field. It seems to me from the NEI presentation that the situation is pretty much under control, but doing that it seems to me that the response to the Generic Letter

should be relatively easy. And I wonder if maybe to reduce the burden if the Staff might be open to a generic response from EPRI, or NEI, or something, rather than having each individual utility have to reply. We have a generic response, my only thoughts.

CHAIRMAN BALLINGER: Steve?

MEMBER SKILLMAN: I appreciate the presentations that have been made, a lot of detail has been provided to us. One concern I have is that when I look through the way in which the questions to the licensees in the Generic Letter have been phrased, I am not convinced that it will be easy for the licensees to address them. I think the Generic Letter should have additional guidance provided to reduce that burden, either by providing very clear identification of, if you will, a tiered approach so that licensees that really ought not to be providing a lot of information for a variety of reasons can very clearly understand what they don't need to provide, and what they do need to provide. There are some fairly open questions in the Generic Letter right now that at least to me could suggest the need to provide detail which licensees won't have, and which they will feel they need to provide. I just don't think it's as clear at this point, as it should be.

CHAIRMAN BALLINGER: Okay.

MEMBER SKILLMAN: I have two comments. For the carborundum plants and the Boraflex plants, it seems to me to be an appropriate request that the licensees be asked to confirm that they're within their design and licensing basis for the pool. I think that's a fair request. It makes good sense, makes good nuclear safety sense.

Relative to the Generic Letter, most of the requested information should be available with moderate effort. And I spent a lot of time at plants, and I've signed a lot of stuff under oath and affidavit, and it's a pain in the neck. But every once in a while one of these things comes along that's worth it, and criticality safety in the pool when there can be a degradation mechanism that you haven't looked at smacks of that importance. So, I can understand strong push back, but I think all of us who have been in the industry for a long time know that if you haven't looked, you've probably missed something, so I think there's value in looking.

Now, the degree to which that exploration is extended is a judgment call, but I certainly don't fault the NRC for saying we have evidence that suggests this needs to be looked at. Please go look at it, give

us your data. I support that. Thank you.

CHAIRMAN BALLINGER: Member Stetkar.

MEMBER STETKAR: I don't have anything to add, sir. Thank you.

CHAIRMAN BALLINGER: Dr. Shack.

CONSULTANT SHACK: I think I agree with Dick. I mean, this is a problem that's been around for a long time. You know, we've had a series of Information Notices, we've had a series of Generic Letters. You know, the guys that don't have neutron absorbing material credited should be able to answer this pretty quickly. And those that are taking credit for it, I think the information requested seems reasonable.

CHAIRMAN BALLINGER: Joy.

MEMBER REMPE: I actually tend to agree with the two of you, but I also have some additional requests that came out during the meeting, and I would like to emphasize those. First of all, NEI has promised to provide us an EPRI report documenting evidence that Boral isn't affected by radiation or flow, and you'll get that document to us somehow or other.

MR. CUMMINGS: That's my recollection of the B-

(Simultaneous speech)

MEMBER REMPE: During the discussion I

raised a question several times about how many B- and I know the NRC said well, we can't tell you exactly, but I did ask how many licensees are crediting neutron absorbing materials at this time? I think this is on Boraflex and carborundum. And, again, I can understand some were in flux, but can we have some idea? Are we talking about five plants, or 20 plants? You know, give us some better metric because, again, counting the list is all I can do at this time.

We heard that a list of plants who were found to be outside the bounds established by the assumptions of the criticality analysis of record. Which plants, how many, what materials were they using, was it just Boraflex and carborundum, I assume, and how much were they outside the bounds of their licensing basis, and what was done to resolve this issue?

And then I asked, and I guess, I mean, from both sides, the NRC and NEI, I've heard we don't know, but it would really be nice to know how an adjusted RACKLIFE prediction that's been adjusted to reflect the recent BADGER or SuperBADGER, that aging measures compares with the next measurement that's made. I mean, how far off are you on your predictive capabilities at this time? And I know you may not know until you get design and evaluations, but somebody probably has some

estimate of that. And I sure would be interested in knowing what it is.

MR. WOOD: Zion is only for Boral. It won't B- the B-

MEMBER REMPE: Oh, that's right, right. Boral, so for the Boraflex, I sure would like to know it. And that's it. Thank you.

CHAIRMAN BALLINGER: Any other questions? Well, I have succeeded in probably getting the Staff made, and probably the Chairman mad by going over a half an hour, about 28 minutes. But B-

PARTICIPANT: Not bad for an amateur. It will show on your performance review.

(Simultaneous speech)

CHAIRMAN BALLINGER: So, we are now B- we're adjourned until I'm going to claim 1:30.

MEMBER STETKAR: Well, make sure.

CHAIRMAN BALLINGER: Yes, that's a good question.

MEMBER STETKAR: Fine. Well, we have flexibility in terms of Subcommittees.

(Simultaneous speech)

MEMBER STETKAR: Start it early we can't do.

CONSULTANT SHACK: Starting early we can't do.

MEMBER STETKAR: 1:30 sounds good.

CHAIRMAN BALLINGER: Yes, the afternoon session is information-only. Right?

CONSULTANT SHACK: But just make sure the Staff knows that B-

PARTICIPANT: It's your call.

CONSULTANT SHACK: It's your call. You're the Subcommittee Chairman. This is your B-

CHAIRMAN BALLINGER: Can we adjourn until 1:30, so we can have an hour for lunch?

PARTICIPANT: That's fine.

CHAIRMAN BALLINGER: Okay. 1:30, it is. Thank you guys very much.

(Whereupon, the above-entitled matter went off the record at 12:28 p.m.)

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

Generic Letter
Monitoring of Neutron-Absorbing Materials in Spent Fuel Pools

ACRS Subcommittee Meeting

Metallurgy & Reactor Fuels

August 21, 2014

NRC Opening Remarks

Timothy McGinty – Division Director
Office of Nuclear Reactor Regulation
Division of Safety Systems

ACRS Subcommittee Meeting
Metallurgy & Reactor Fuels
August 21, 2014

The Big Picture

Licensees submit criticality analyses to the NRC as part of the license approval process to demonstrate they meet NRC subcriticality requirements. Many licensees credit neutron-absorbing materials for this purpose. The NRC has recently seen situations where licensees found previously unidentified degradation of neutron-absorbing materials or had ineffective monitoring programs for their neutron-absorbing materials. In several cases, the neutron-absorbing materials were found to be outside the bounds established by the assumptions of the criticality analyses of record.

Generic Letter

Degradation of neutron-absorbing materials used in the spent fuel pool is a safety issue that nuclear power reactor licensees have been dealing with since the 1980s (Boraflex). Recent events have raised concerns among NRC staff that some licensees may not have adequate methodologies and surveillance programs to monitor and assess the degradation and deformation of neutron-absorbing materials in the spent fuel pool.

Generic Letter

This is not an immediate safety concern, but it is a safety concern. Unidentified and unmitigated neutron-absorbing materials degradation constitutes an unchecked reduction in the subcriticality margin (i.e. loss of shutdown margin) which has the potential to lead to a local criticality in the spent fuel pool.

Generic Letter

This Generic Letter is asking licensees to provide information regarding their neutron-absorbing materials monitoring programs and the basis for them. The NRC staff believes the licensee should have this information available, under 10 CFR 50 Appendix B record-keeping requirements. The Generic Letter is not requesting any new analyses, programs, or research.

U.S.NRC

UNITED STATES NUCLEAR REGULATORY COMMISSION

Protecting People and the Environment

Nuclear Criticality Analyses

Kent Wood

Office of Nuclear Reactor Regulation

Division of Safety Systems

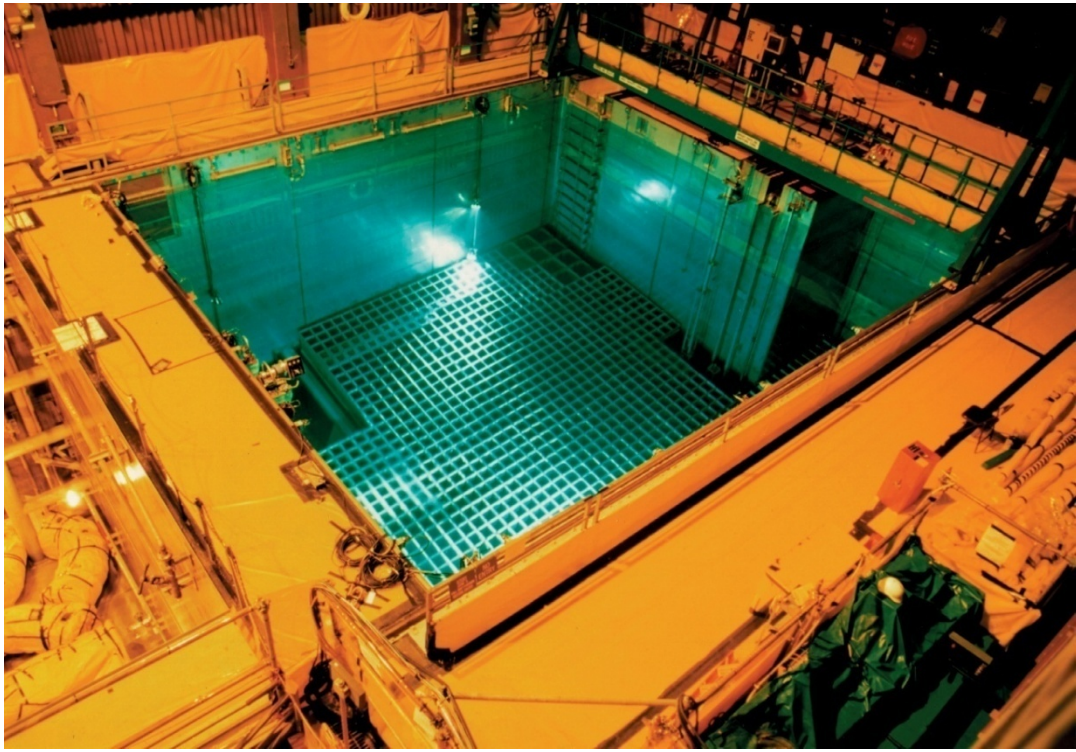
ACRS Subcommittee Meeting

Metallurgy & Reactor Fuels

August 21, 2014

Overview

- Requirements
- Background
- Minimum Critical Volume
- Neutron Absorbers
- Rack Designs
- Reactivity Effect
- Summary



Picture: Spent Fuel Pool

Requirements

- 10 CFR 70.24
  - Monitor/Detect/Mitigate/Recover
  - Emergency Plan/Drills
- 10 CFR 50 Appendix A GDC
  - 61: Fuel Storage & Handling and Radioactivity Control
  - 62: Prevention of Criticality in Fuel Storage & Handling
- 10 CFR 50.68
  - Don't credit soluble boron; $k_{eff} \leq 0.95$ at 95/95
  - Do credit soluble boron: $k_{eff} < 1.0$ w/o [B] at 95/95 AND $k_{eff} \leq 0.95$ at 95/95 w/ [B]
    - $k_{eff} < 1.0$ w/o [B] is to account for design basis accidents
- 10 CFR 50.36
  - Design Features
  - Limiting Conditions for Operation

Background

- High capacity SFP storage designs
- Neutron absorber degradation
- More reactive fuel assemblies
  - Higher enrichment
  - Core design & operating parameters
- SFP NCS analyses & controls more complex
  - Analyses continue to take new approaches
  - More storage configurations

Minimum Critical Volume

Shika 1 ICE Core

- Control Rods
  - 89 Total
  - 3 Moved
- Displacement
  - A: 16 steps
  - B: 20 steps
  - C: 08 steps
  - The rest: 0
- Core periphery
  - Leakage
- Local Condition of NAM

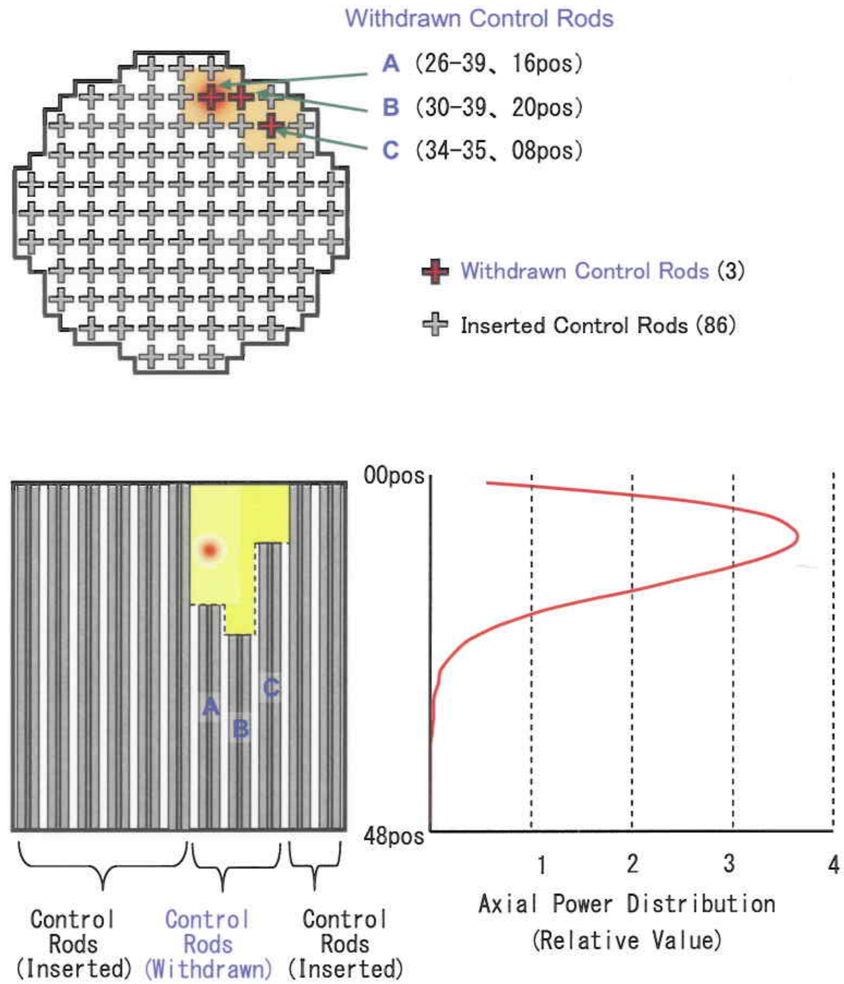


Figure 2 Power Distribution of the Core

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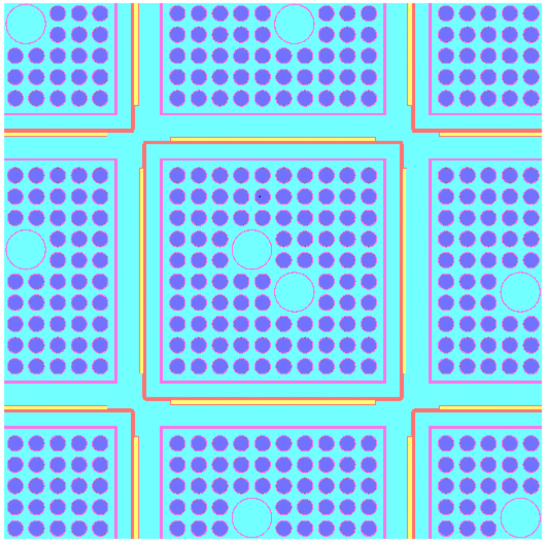
Neutron Absorbing Materials

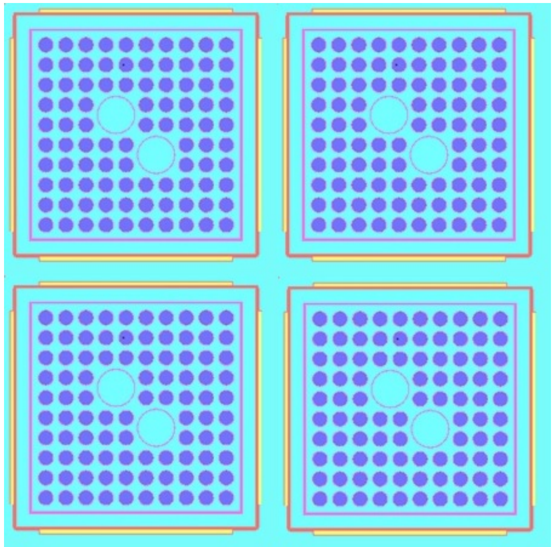
- Naturally occurring ^{10}B as B_4C captured in some other material
- "other material"
  - Silicone Rubber, phenolic resin, aluminum, stainless steel
  - Function is to hold the B_4C in place during normal and abnormal conditions
- B_4C is non-soluble
  - Will fall to bottom of SFP if "other material" breaks down.

SFP Rack Designs

- High Density
  - Common for BWR and PWR Region 2
  - Typical panel initial areal density ~ 0.022 gm $^{10}B/cm^2$
- Moderate Density
  - Array of the central box attached to a frame so there is a small gap between the boxes.
  - Two poison panels & small flux trap
  - Typical panel initial areal density ~ 0.022 gm $^{10}B/cm^2$



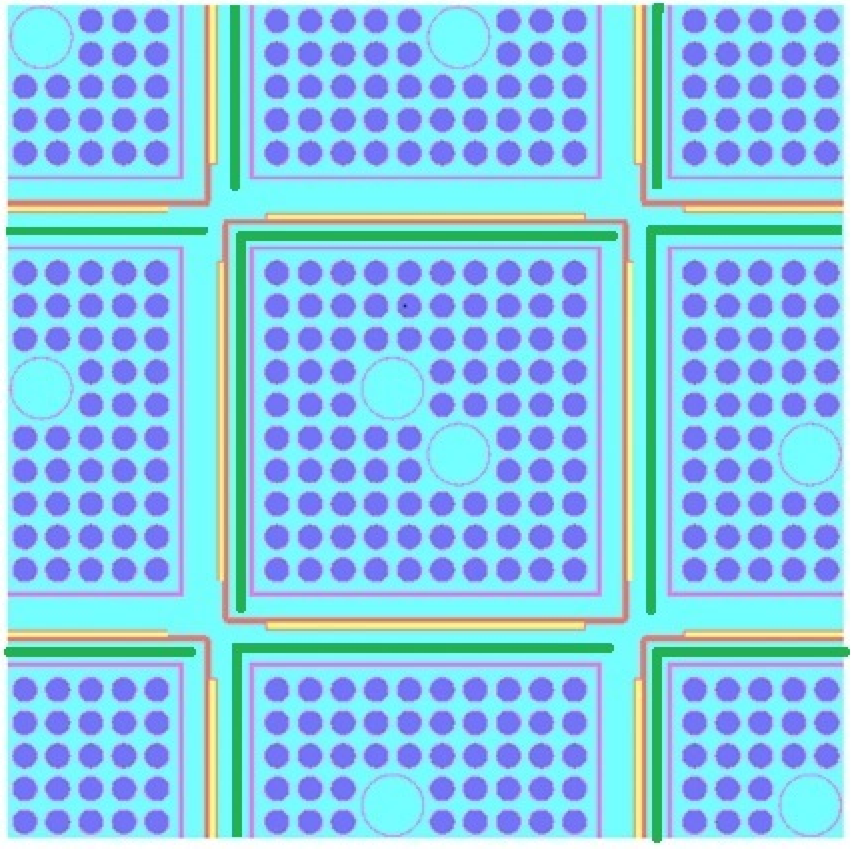
High density



Moderate density (flux trap)

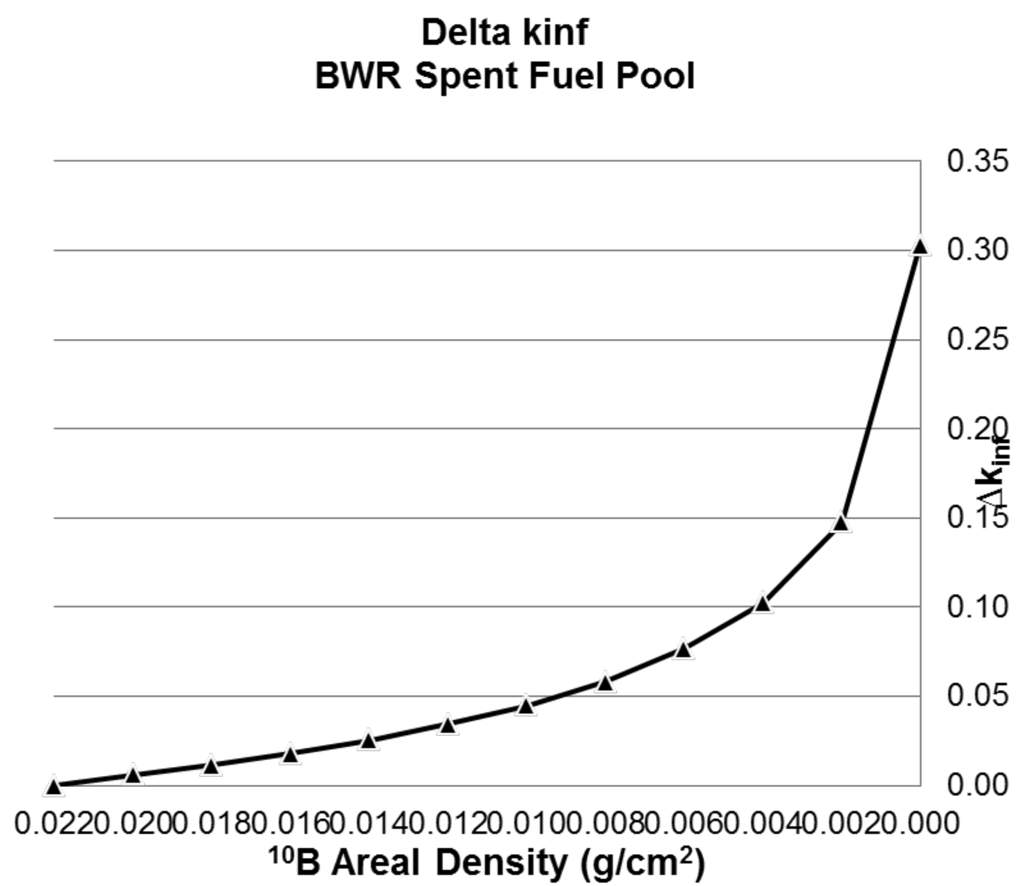
SFP Rack Designs

- Inserts
  - NAM placed in the cell with the fuel assembly
  - Typical insert initial areal density ~ 0.010 gm $^{10}B/cm^2$
- Regulatory compliance established in AOR at initial ^{10}B areal density



Reactivity Effect

- Typically SFP NCS Analysis have ~ 0.005 Δk to regulatory limit.
- Compliance/Safety
  - Initially a compliance issue.
  - As degradation progresses it becomes a safety issue
  - As degradation progresses response to events becomes more of a concern
- Key is knowing condition of NAM



Summary

When neutron absorbing materials are credited to meet sub-critical requirements their unidentified and unmitigated degradation poses a safety concern because an unchecked reduction in the margin to sub-criticality has the potential to lead to a local inadvertent criticality event in the SFP.

Acronyms

- GDC: General Design Criteria
- NCS: Nuclear Criticality Safety
- NAM: Neutron Absorbing Material
- BWR: Boiling Water Reactor
- PWR: Pressurized Water Reactor
- SFP: Spent Fuel Pool
- AOR: Analysis of Record
- k_{inf}: k-infinity

Technical Perspective on SFP Neutron-Absorbing Material Degradation

Dr. April Pulvirenti
Office of Nuclear Regulatory Research
Division of Engineering

ACRS Subcommittee Meeting

Metallurgy & Reactor Fuels

August 21, 2014

Neutron Absorber Related Research

- Spent Fuel Pool Criticality Management Database, ML14024A142 and ML113550241
- Monitoring Degradation of Phenolic Resin-Based Neutron Absorbers in Spent Nuclear Fuel Pools (NRC, Al-Sheikhly), ML13141A182
- “Boraflex, RACKLIFE, and BADGER, Description and Uncertainties” (T.C. Haley), ML12216A304
- “Initial Assessment of the Uncertainties Associated with the BADGER Methodology” (ORNL), ML12254A064
- Current focus
  - SuperBADGER
  - Boral

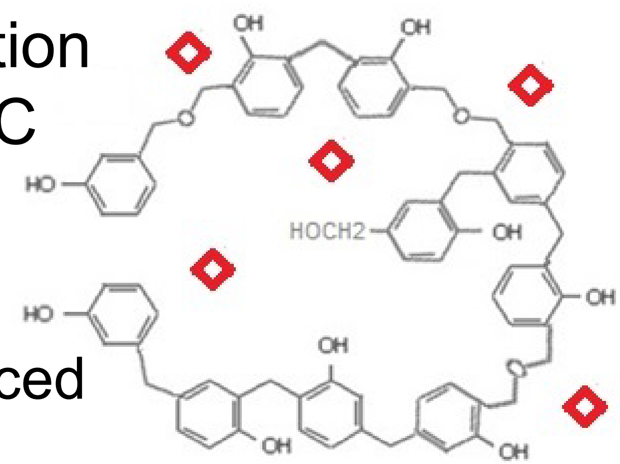
SFP Management Spreadsheet

- Lists how each pool meets the subcriticality requirements
- References the applicable licensing document
- Accompanied by an explanatory Technical Letter Report
- Latest Update: March 2014

Phenolic Resins

- B_4C particles encased in a phenolic resin matrix

- Polymer backbone degraded by irradiation and the pool environment, releasing B_4C particles



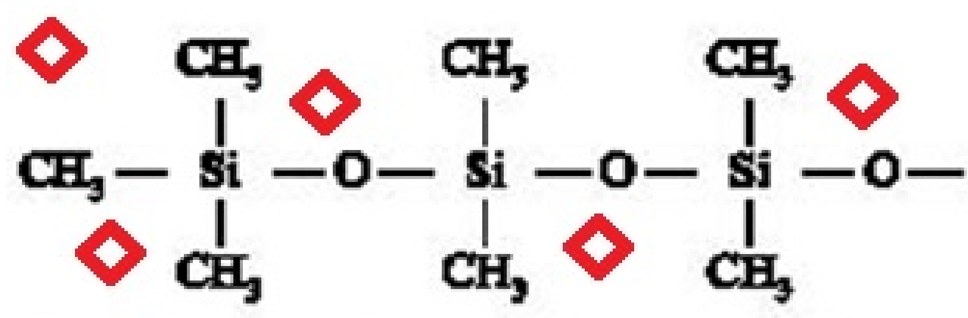
  - Modes and rates of degradation influenced by the specific panel environment

  - Ability of degraded matrix to retain B_4C not well known

- Limited ability to predict the loss of B_4C

Boraflex

- B_4C particles encased in a silicone matrix



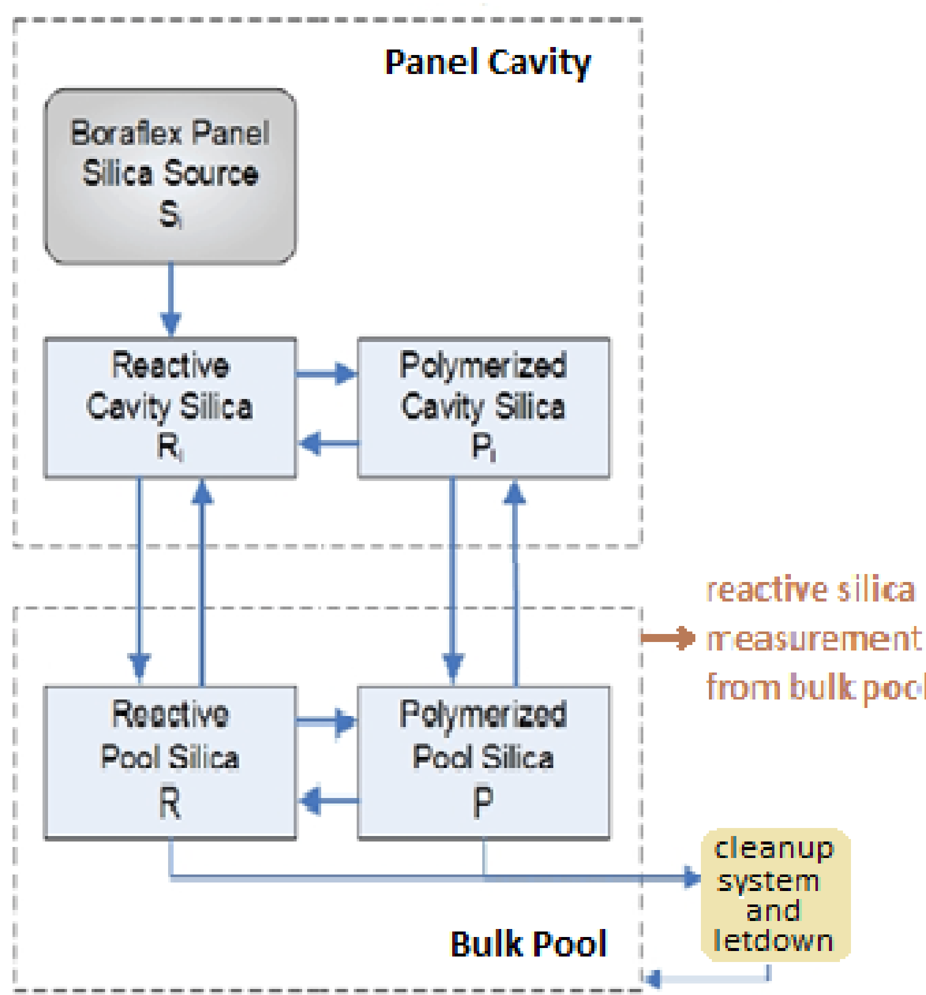
- Multi-step degradation
  1. γ → cross-linking and shrinkage, which leads to gaps
  2. γ → conversion of silicone polymer backbone into slightly soluble silica particles
  3. Pool flow → dissolution of silica particles, release of B_4C

RACKLIFE

Predictive program for the loss of B-10

– Cumulative gamma dose is used to predict polymer degradation

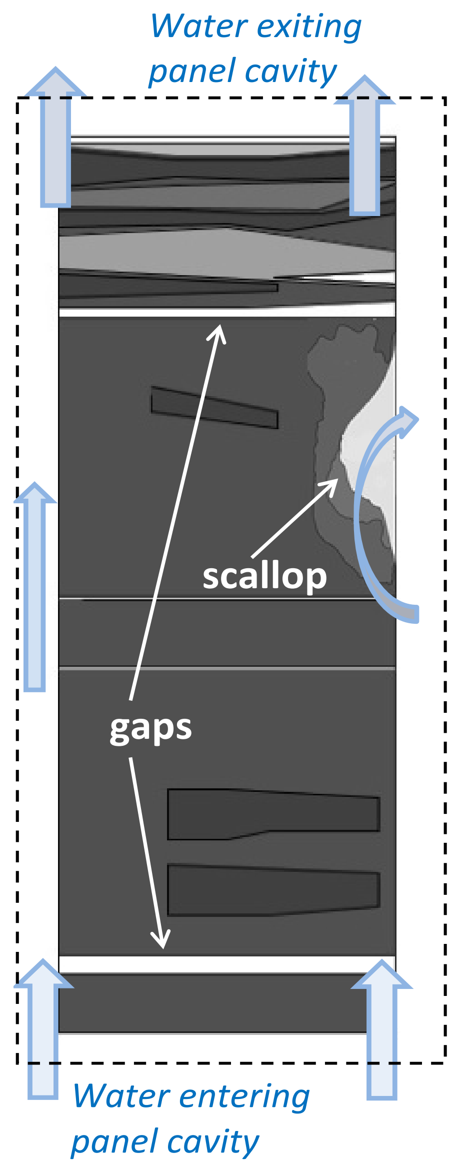
– Measured pool silica is used as input into a silica transport model to predict silica and B-10 loss from the panel



T.C. Haley, 2012

RACKLIFE Uncertainties

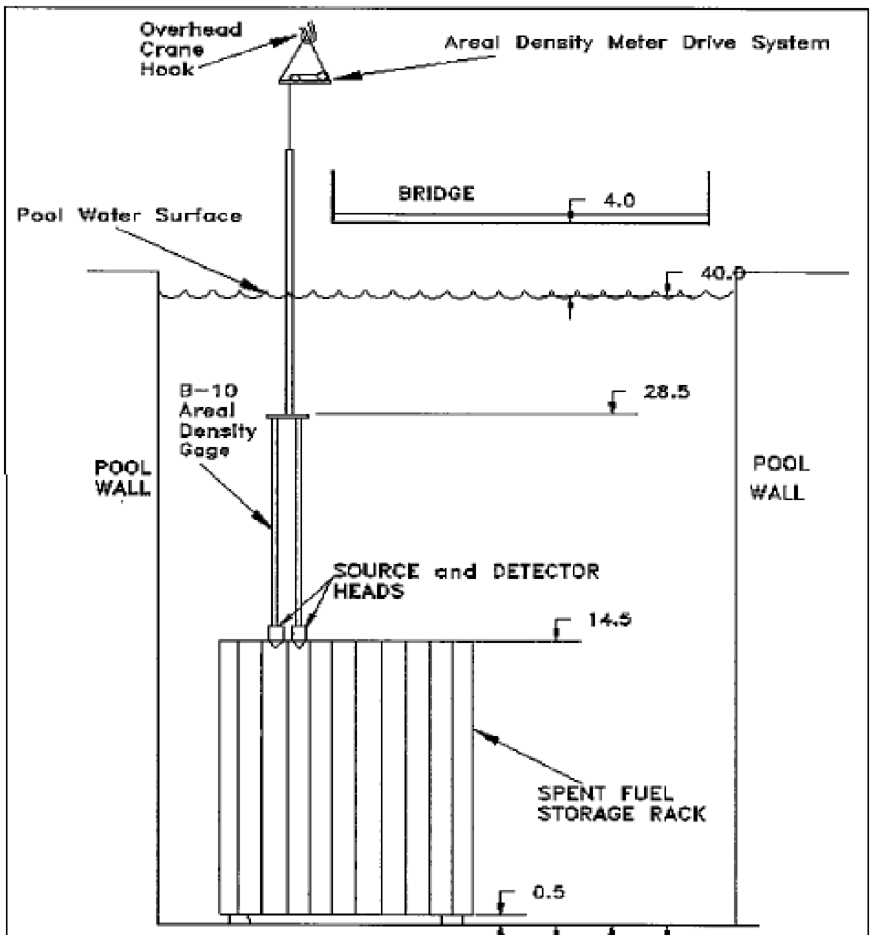
- Pool silica measurement may not be an accurate input
- Escape Coefficient (panel cavity exchanges/day)
  - Tuned to match silica levels
- Non-uniform degradation
  - Not well represented by the linear silica transport model
  - As degradation progresses it becomes increasingly non-uniform



Adapted from T.C. Haley, 2012

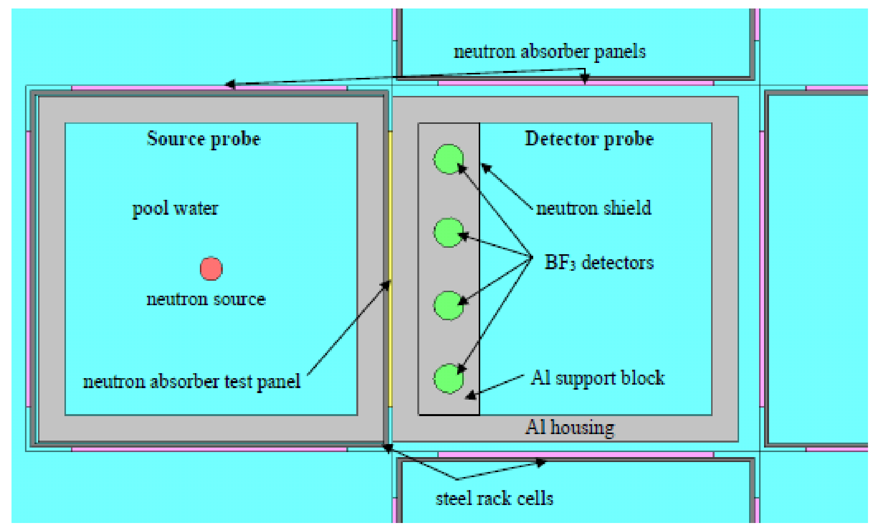
BADGER
(assessed before SuperBADGER)

Boron Areal Density Gauge for Evaluating Racks



EPRI TR-107335

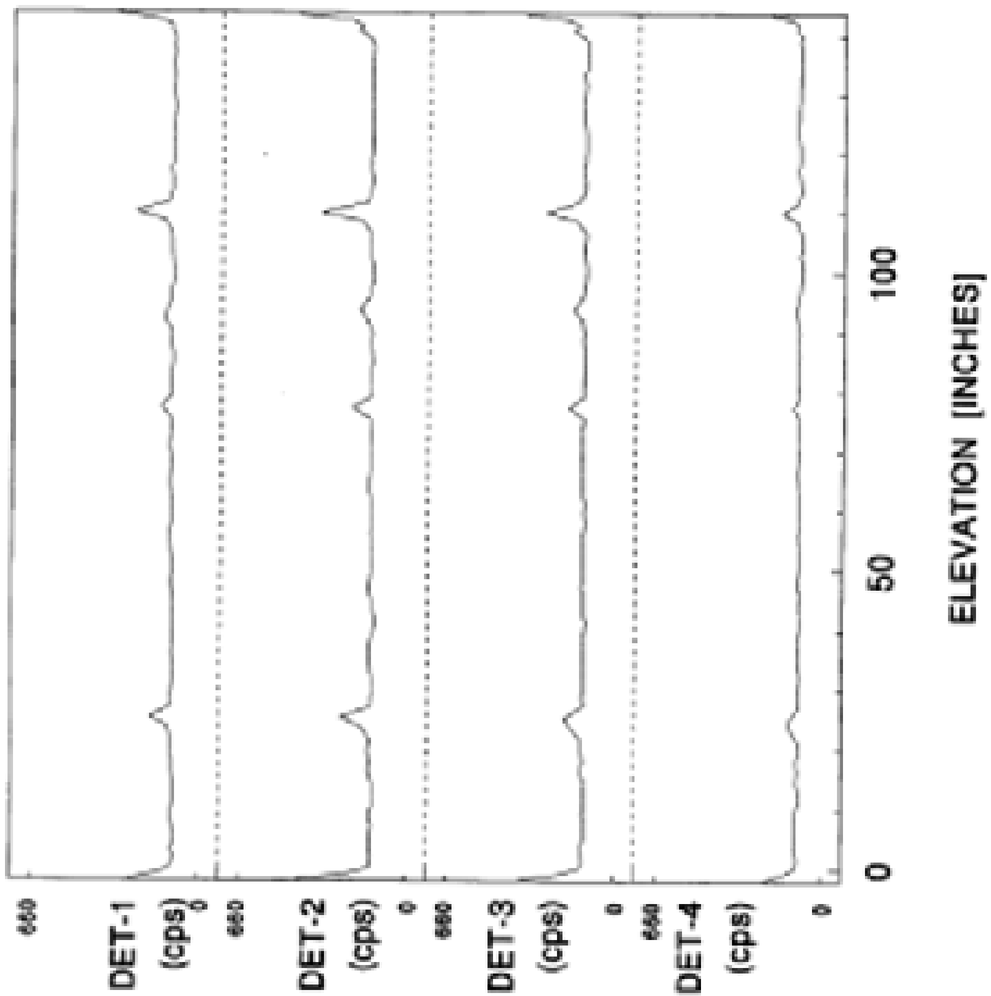
Measures ^{10}B areal density independent of material

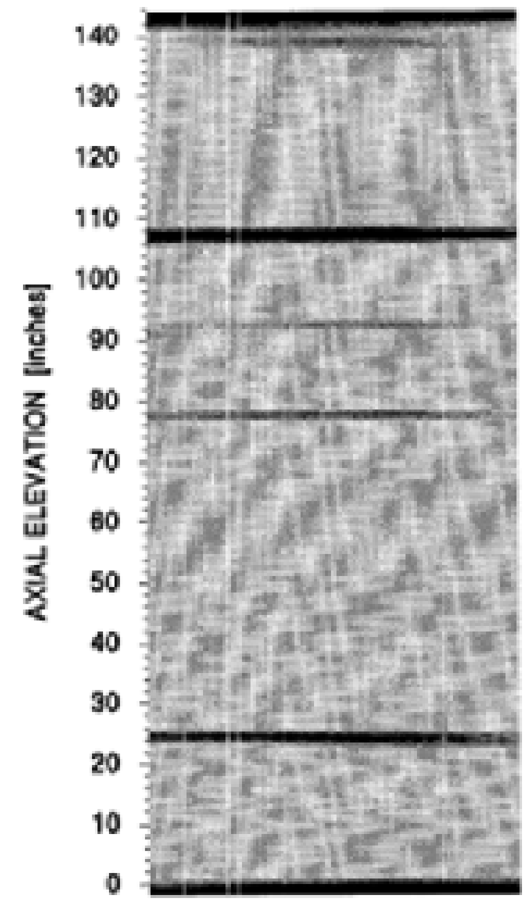


Bird's eye view of BADGER source and detector heads

Scaglione et al, 2012

BADGER Scan of a Boraflex Panel





2-D representation of detector output

EPRI TR-107335

BADGER uncertainties

- Neutron source
  - Count times of ~10 seconds may result in low neutron counts
  - Count rate impacted by source head moderator, pool conditions, and flux traps
- Gamma interference
  - Calibration/efficiency
  - Discriminator settings
  - Pile-up pulse
  - Wall effect

Exacerbated by small detector size (applies to Pile-up pulse and Wall effect)

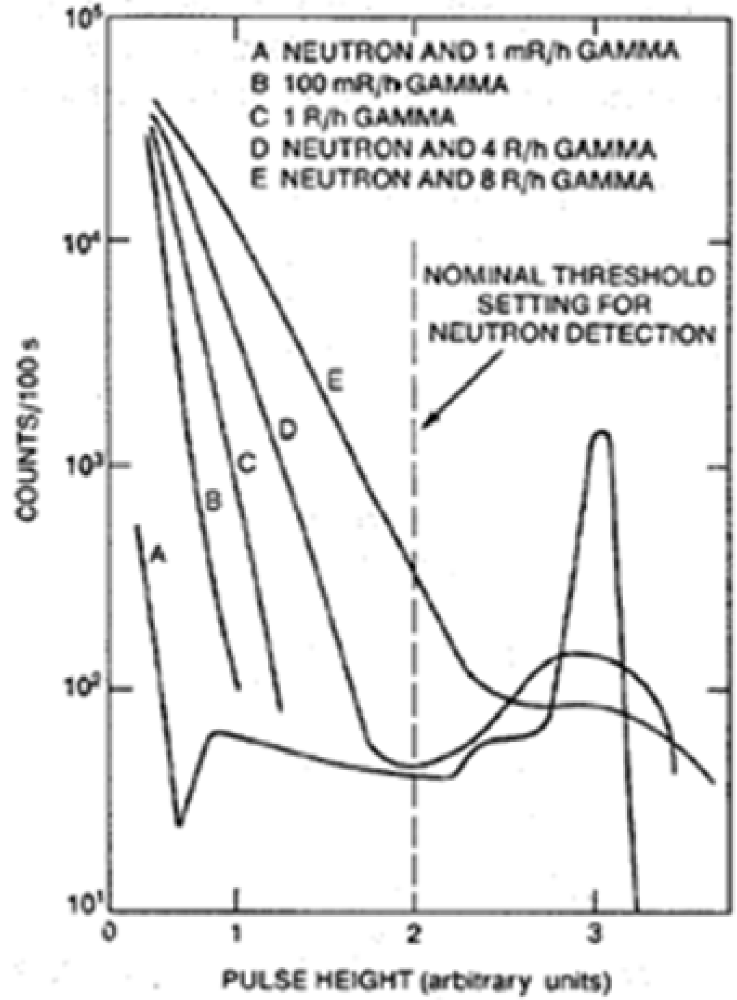
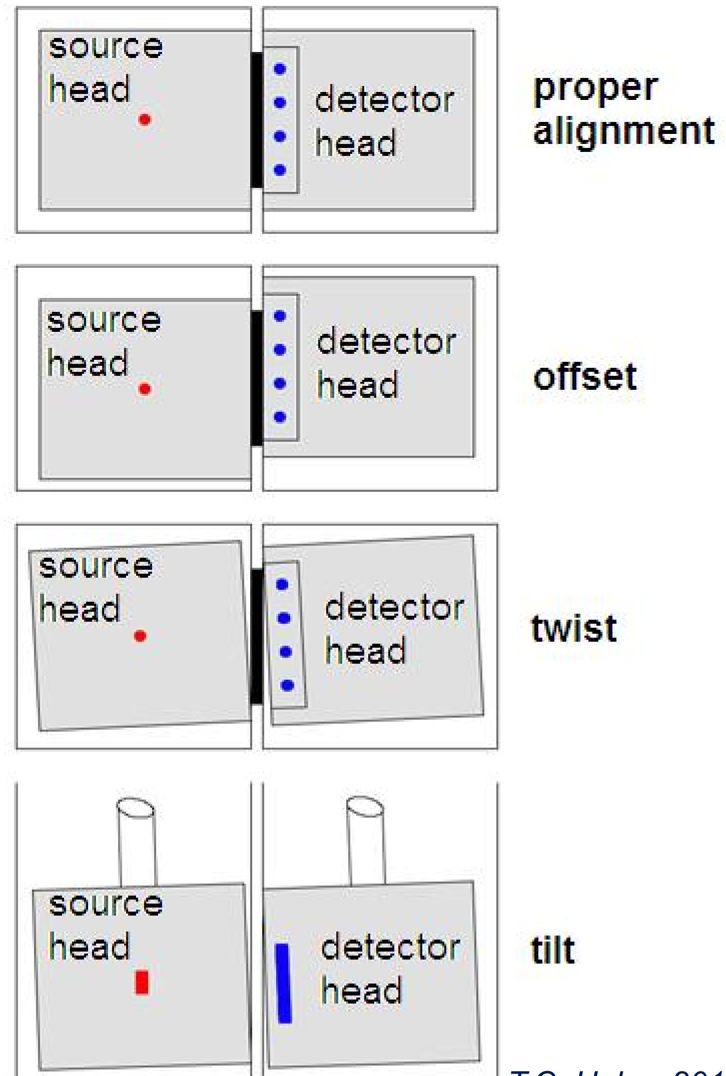


Fig. 13.8 ***Gamma-ray pile-up effects for a ^{3}He proportional counter tube 2.54 cm in diameter and 50.8 cm in length.***

T.C. Haley, 2012

BADGER uncertainties

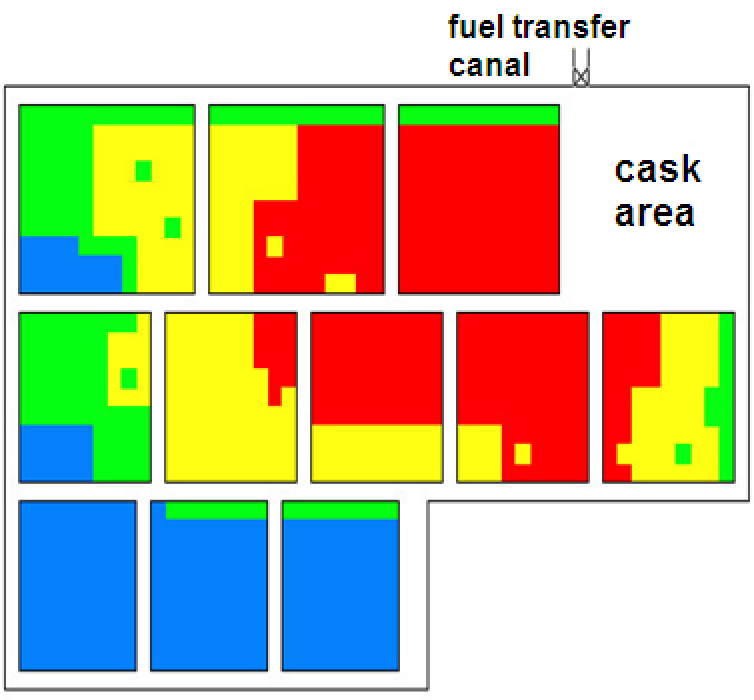
- Calibration
  - Potential for material mismatch
  - Use of zero-dose panel as a nominal reference
  - Effect of flux trap
- Head Misalignment
  - Errors are magnified by close proximity of source and detector
  - No real-time detection of misalignment



T.C. Haley, 2012

BADGER uncertainties

- A typical BADGER campaign tests ~30-60 panels out of a ~3000-4000 panels in a pool
  - RACKLIFE is used to inform BADGER panel selection for Boraflex
  - No predictive method exists for other neutron absorbers



T.C. Haley, 2012

Current Focus

Draft Addendum to the EPRI Memorandum of Understanding regarding neutron absorbers at the Zion spent fuel pool :

- Observe a SuperBADGER measurement campaign
- Harvest and test Boral coupons and Boral samples from the spent fuel pool racks

Generic Letter Background

Scott Krepel
Office of Nuclear Reactor Regulation
Division of Safety Systems

ACRS Subcommittee Meeting
Metallurgy & Reactor Fuels
August 21, 2014

Regulatory Basis

- Regulatory criteria to prevent the occurrence of inadvertent criticality events in the SFP
  - 10 CFR 50.68
  - GDC 62

- Licensees submit nuclear criticality safety analyses to demonstrate that the criteria are met

Boraflex

- Information Notices (INs) 87-43, 93-70, 95-38
  - Degradation of Boraflex at multiple facilities
- Generic Letter (GL) 96-04
  - Requested information on current state of Boraflex and monitoring/corrective actions

Boral

- IN 83-29
  - Bulging of panels containing Boral

- IN 09-26
  - Boral deformation

Carborundum

- IN 09-26
  - Carborundum degradation
- Technical Letter Report
  - Discusses carborundum degradation and monitoring/qualification programs

Monitoring Programs

- IN 12-13
  - Deficiencies in Boraflex monitoring programs

- Technical Letter Reports
  - Identified potential uncertainties in existing methodologies currently used by licensees to monitor Boraflex
    - RACKLIFE
    - BADGER

NRC Guidance Updates

- Update to Generic Aging Lessons Learned (GALL) Report
  - Incorporated aging management guidance for all neutron-absorbing materials
- Interim Staff Guidance: DSS-ISG-2010-01
  - Criticality analysis guidance

Current NRC Regulatory Actions

- Current License Amendment Request (LAR) reviews

- NRC-Industry engagement
  - Regulatory Information Conference (RIC)
  - Neutron Absorber User's Group (NAUG)
  - Various public meetings

- Generic Letter

Generic Letter Information Request

Matthew Yoder

Office of Nuclear Reactor Regulation

Division of Engineering

ACRS Subcommittee Meeting

Metallurgy & Reactor Fuels

August 21, 2014

Draft Generic Letter: Purpose

Request information demonstrating that credited neutron-absorbing materials in the spent fuel pool are in compliance with the current licensing and design basis, as well as applicable regulatory requirements

Determine if additional regulatory action is required

Information Requested

1. Material properties and configuration

2. Surveillance program methodologies

3. Surveillance program frequencies

4. Criticality analysis modeling of the material and degraded material

5. Design basis event considerations

Material Properties

- Material Type
- Manufacturer
- Material Age
- As-Built Areal Density
- Physical Characteristics
- Qualification Testing
- Configuration in Pool
- Current Areal Density
- Credited Areal Density
- Operating Experience

Surveillance Methodology

- Technique
  - Visual
  - Coupons
  - In-situ
- Parameters Inspected
- Sample Size
- Acceptance Criteria
- Standards Used
- Data Trending
- Predictive Codes

There are a number of specific sub-questions associated with:

- RACKLIFE
- BADGER

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Surveillance Methodology

BADGER

- Method and criteria for choosing panels to be tested
- Trending of test data and any re-testing of panels in subsequent campaigns
- Accounting for sources of uncertainty
  - Rack cell deformation,
  - Head or detector misalignment
- Calibration
  - Material in standard vs. material in racks
  - How does the standard account for potential rack degradation?
  - Reference panel used?
    - Same reference panel for all campaigns?
    - Selection of reference panel?

Surveillance Methodology

RACKLIFE

- Version (Rev.) of RACKLIFE being used
- Frequency at which RACKLIFE code is run
- Describe the confirmatory testing being performed (e.g., in-situ)
  - How does the RACKLIFE prediction compare to measured values for neutron attenuation?
- Describe the RACKLIFE calculation for your plant including
  - Escape Coefficient and total silica release rate
  - Average areal density or panel-specific
  - Starting point for areal density calculation? (minimum certified, credited value in criticality analysis, actual as-manufactured, minimum as-manufactured, or nominal)

Surveillance Frequency

Technical Justification for the Interval Between Inspections

Based on:

- Material Type
- Inspection Type
- Sample Size
- Operating Experience

Criticality Analysis

- How are the neutron absorbers modeled?
- How does the surveillance program inform the analysis?
- How are uncertainties in the surveillance accounted for?
- How is degradation, or potential degradation, of the absorber material accounted for?

Design Basis Event

Technical basis for why the credited neutron absorber materials will maintain their intended safety function under a design basis event (e.g. seismic event).

Possible effects may include:

- Shifting or settling relative to the active fuel
- Increased dissolution or corrosion
- Changes of state or loss of material properties that hinder the neutron absorbing material's ability to perform its safety function

Conclusion

The NRC is not requiring any new analyses, new programs, or new research to be developed and implemented.

The information being requested should be maintained by licensees in accordance with provisions found in Appendix B of 10 CFR 50.

The NRC is requesting this information in order to determine compliance.

Based on a review of the responses the staff will determine if additional regulatory actions are warranted.

NRC Response to Public Comments on Draft Generic Letter

Scott Krepel
Office of Nuclear Reactor Regulation
Division of Safety Systems

ACRS Subcommittee Meeting

Metallurgy & Reactor Fuels

August 21, 2014

Public Comments

- 11 letters received during public comment solicitation period

- Most significant comments were captured in letter from Nuclear Energy Institute (NEI)

Main Concerns

- Scope of GL
- Time required to respond
- Relevance of Issue

Scope

- No new analyses, research, or programs
- Provide information from existing records
  - If not applicable, state as such
  - If available in a NRC-approved license amendment request, reference it
  - If available in licensee records, provide it
  - If not available, state as such

Time Required for Response

- Time will be increased for administrative burden

- GL scope does not merit further increase

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Relevance

- Subcriticality margin that forms part of a plant's licensing basis should not be credited to address issues not considered when the licensing basis was approved (e.g., no double-counting of margin)
- Recent operating experience shows that effective monitoring is necessary to ensure compliance

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Summary

- Management of degradation of neutron-absorbing materials is a compliance and safety issue

- Recent events have raised concerns that current monitoring may not be adequate

- Therefore, the NRC is requesting information that licensees should have readily available

Industry View on Neutron Absorber Degradation

Kristopher Cummings

Sr. Project Manager, Used Fuel Programs

August 21st, 2014 • Rockville, MD

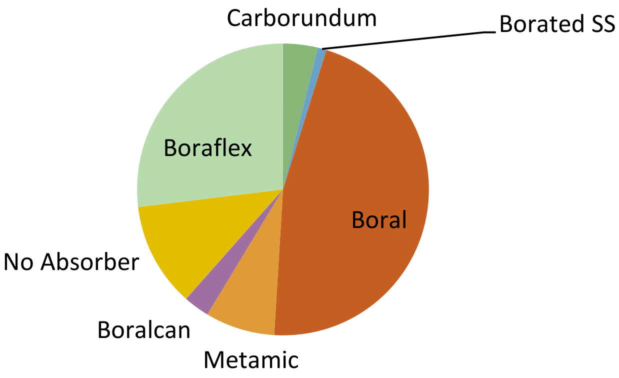
Topics of Discussion

- Types of Neutron Absorbers in Use
- Neutron Absorber Testing Program
- Is this a Safety Concern?
- Ongoing Industry Efforts
- Alternative Proposal
- Summary/Conclusions

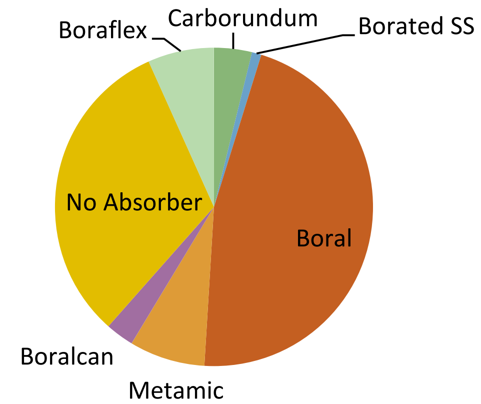
Types of Neutron Absorbers in Use

- Carborundum/Tetrabor
- Borated Stainless Steel
- Boraflex
- Boral
- Metamic
- Boralcan

Installed Neutron Absorber



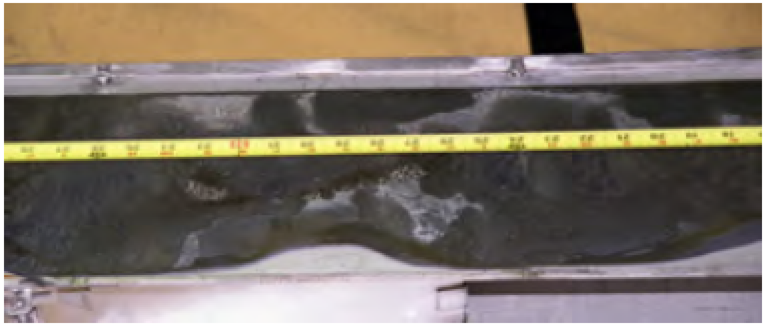
Credited Neutron Absorber



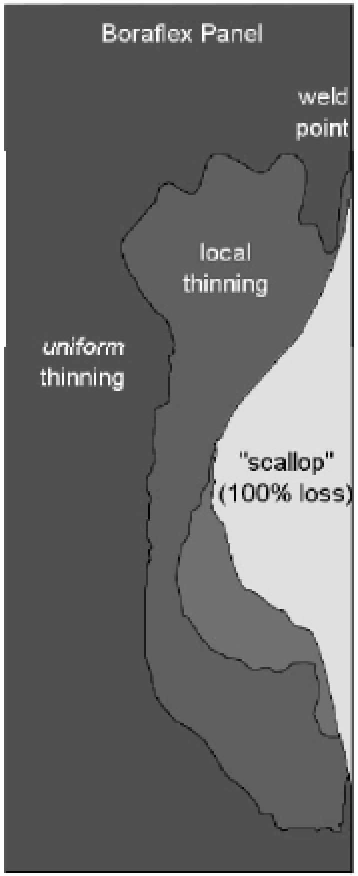
Results based on a partial survey of the industry

Boraflex

- Boraflex consists of B_4C particles bound in a silicone rubber matrix
- Degradation mechanism is based on a threshold gamma dose and exposure to pool water (especially flowing water)
- Degradation causes dissolution of silica into pool water and loss of B_4C from matrix



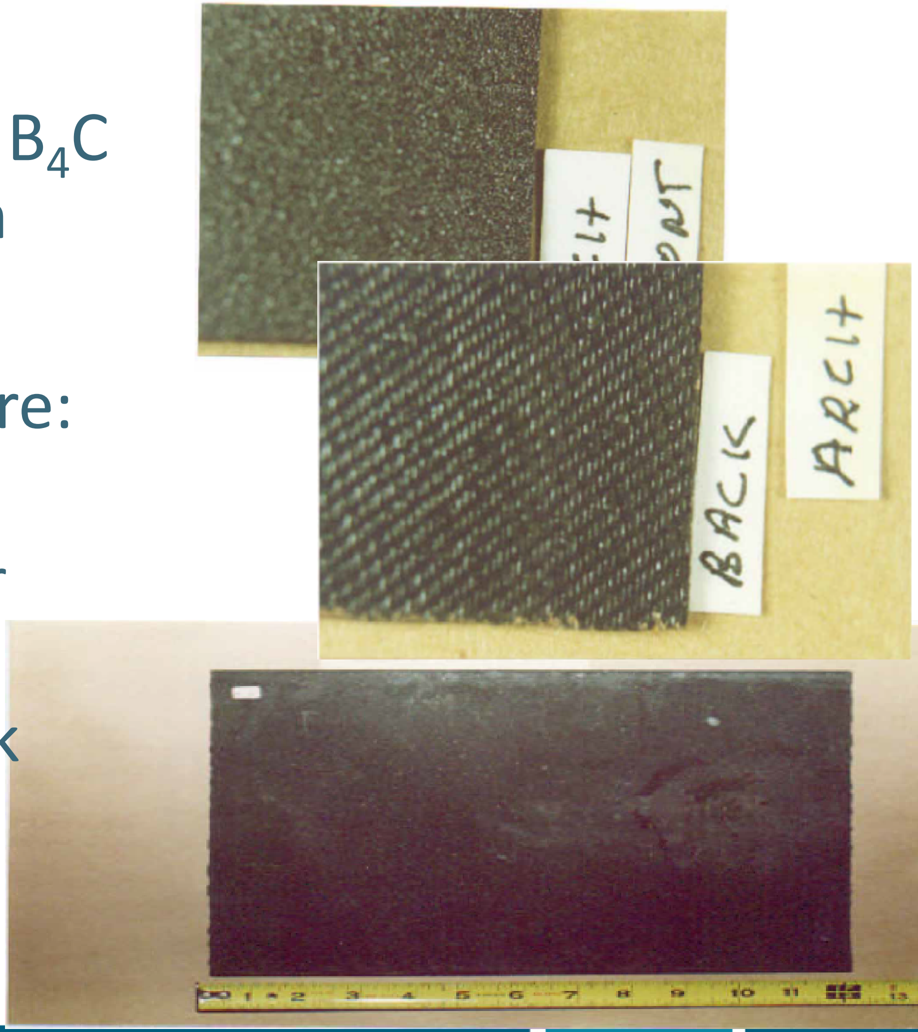
EPRI Report 1003414



T.C. Haley, 2012

Carborundum/Tetrabor

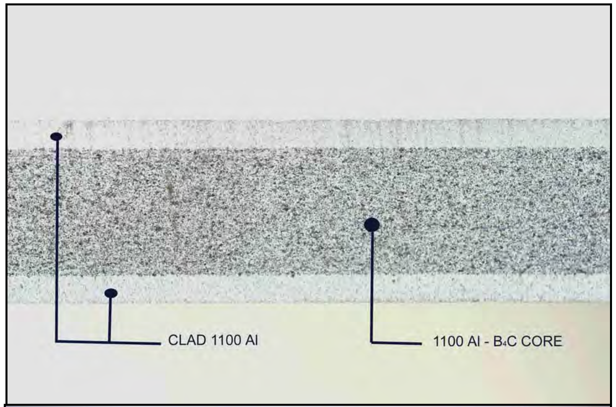
- Carborundum/Tetrabor are B_4C particles in a Phenolic Resin
- Plate and sheet type
- Aging/Degradation issues are:
  - Loss of weight
  - Off-gassing from pool water exposure
- Plate type is extremely thick (0.25”) and black (0.1 g $^{10}B/cm^2$)

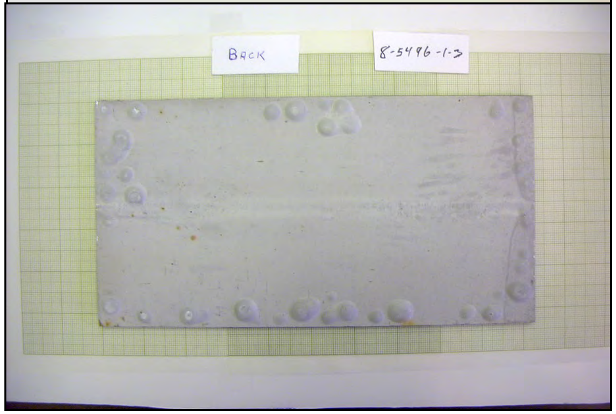


EPRI Report 1019110

Boral

- Boral is an Aluminum Boron Carbide Cermet
- Aging issues are:
  - Blistering (separation of Al clad from core material)
  - Pitting (small, localized)
- No observed loss or redistribution of B_4C.
- No mechanisms identified that could lead to loss of B_4C.
- EPRI Boral database contains data extending over 25 years

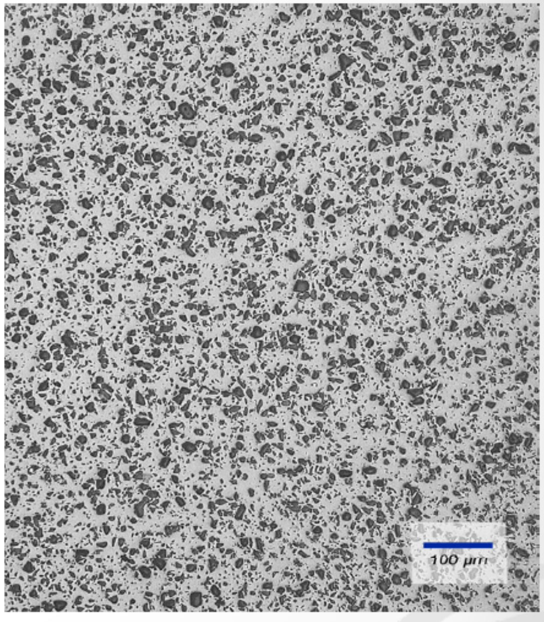




EPRI Reports 1019110 and 1011818

Metal-Matrix Composites (Metamic, Boralcan, etc)

- Metal-matrix materials are fully dense (no porosity)
- Aging issues are:
  - Pitting (small, localized)
  - General Corrosion
- No blistering possible (no Al clad)
- No observed loss or redistribution of B_4C (~10 years in service)
- No mechanisms identified that could lead to loss of B_4C.



EPRI Report 1019110

Neutron Absorbers in Use

- Carborundum/Tetrabor:
  - All plants credit some amount of the neutron absorber and have monitoring programs in place.
- Boraflex:
  - Majority of plants have discontinued credit of neutron absorber:
  - Remainder of plants have LARs for inserts, LARs to remove credit, or monitor via coupons/in-situ testing.
- Boral:
  - Over 50% of the plants have coupon testing programs (provides adequate sister site/surrogate programs)
  - Those plants licensed without coupon testing are adding coupons, in-situ testing and/or monitoring fleet/industry results.
- Metamic/Boralcan: All have coupon monitoring programs

Neutron Absorber Testing

The purpose of a Neutron Absorber Testing Program is to provide ongoing confirmation that:

- The neutron absorber material is not undergoing unanticipated aging effects that would impact reactivity
- Onset of material aging effects are observed in coupons in advance of expected degradation in racks and accounted for in the criticality analysis
- The presence of the neutron absorber material provides the level of reactivity control relied upon in the analysis.

Neutron Absorber Testing (Cont'd)

There are currently two methods for providing ongoing confirmation of the presence of the neutron absorbers in the racks:

- **Coupon Testing -** Preferred method
- **In-Situ Measurements -** Acceptable method for confirming ^{10}B to:
  - Supplement coupon testing
  - In lieu of coupon testing if no coupons available

Coupon Testing

A Coupon Testing Program should meet the following criteria:

- **Number of Coupons -** Sufficient number of coupons to provide sampling at appropriate frequency for intended life of the material
- **Life of Neutron Absorber -** Based on time the material will be credited in the criticality analysis
- **Sampling Frequency -** Based on expected material performance from qualification testing and operational experience
- **Coupon Location -** Located such that exposure to parameters controlling performance attributes (such as gamma fluence and/or heat) are similar to the in-service neutron absorber material. If possible, coupon exposure should bound 95% of the in-service material.

Coupon Testing (cont'd)

A Coupon Testing Program should meet the following criteria: (cont'd)

- **Coupon Testing -** Based on operating history of material as follows:
  - **Basic Testing**
    - Appropriate when testing and operating experience indicates no mechanism resulting in loss of neutron absorbing capability
    - Consists of visual observations, dimensional measurements, and weight.
  - **Full Testing**
    - Appropriate for the first coupon test and when testing and operating experience indicates loss of neutron absorbing capability
    - Consists of ^{10}B areal density measurements, microscopic analysis, and characterization of degradation in addition to Basic Testing

In-Situ Measurement

An In-Situ Measurement Testing Program should meet the following criteria:

- **Number of Panels Tested -** Should be an appropriate statistical sample
- **Sampling Frequency -** Based on expected material performance from qualification testing and operational experience
  - If material does not have a long-term industry in-service history – initial frequency should not exceed 5 years
  - If material has a long-term industry in-service history and material stability has been documented – frequency should not exceed 10 years
- **Measurement Uncertainties -** Measurement method should be appropriately justified, including identifying uncertainties.
- **Use of Results –** Should be material dependent as follows:
  - For material with potential performance experience which do not result in loss of neutron absorbing capability – measurements should be used as confirmatory
  - For material with potential performance experience which may result in loss of neutron absorbing capability – measurements should be performed to justify credit in analysis

Is this a Safety Issue?

- Degradation of older neutron absorbers (Boraflex, Carborundum) have largely been addressed by:
  - elimination of absorber credit
  - installation of new neutron absorber inserts
  - Monitoring/reanalysis with conservative treatment and prediction of neutron absorber presence
- Aging effects for metallic absorbers is a slow process (decades) that provides advance indication through coupon testing, in-situ measurements and pool chemistry observations.
- Large amount of loss of material (50-60%) needed to overcome administrative margin (5% Δk)
- Aging effects (pitting, general corrosion, localized loss of material) has a negligible effect on criticality (< 0.001 Δk). Boral blistering, theoretically could have an impact (0.01 Δk) in flux-trap racks, in reality is a minimal localized effect (0.001 Δk). These effects are addressed in the licensee QA program.

Is this a Safety Issue?

- Significant amounts of independent reactivity hold-down is present in pools:
  - PWR Pools:
    - Soluble boron present in pool to offset unexpected conditions (approximately 2000ppm per Tech Spec = ~0.2 Δk)
  - BWR Pools:
    - Analysis based on maximum reactivity provides significant conservatism (> 0.10 Δk)
    - Regulatory administrative margin (0.05 Δk)

Ongoing Industry Efforts

- **EPRI Accelerated Boral Corrosion Testing** :
  - BWR & PWR Spent Fuel Pool Conditions
  - Five year test program
  - 192 coupons are placed in baths
  - Encapsulated and Un-encapsulated Coupons
  - Various fabrication processes
  - Tests are conducted at 195°F to simulate approximately >60 years of service life
  - First year results showed pitting, no blisters, no loss of areal density

Ongoing Industry Efforts

EPRI Zion Comparative Analysis Project

Zion Station is currently being decommissioned and this provides a unique opportunity to address some of these questions/concerns for both Boral performance and monitoring techniques

Objectives: Perform **comparative analysis** of
- Surveillance sample coupon measurements
- In-situ measurements
- BORAL panel test measurements

- Opportunity to address concerns with comprehensive plant data
  - Boral panels have been in use since 1993; plant shutdown in 1998
- Provide the technical bases that will permit the continued long-term use of Boral based on current surveillance practices

Ongoing Industry Efforts

- NEI 12-16, “Guidance for Performing Criticality Analysis of Fuel Storage at Light Water Reactor Power Plants”:
  - Includes a section on the appropriate monitoring program depending on material and availability of coupons (March 2014)
- Industry continues to share test results, operating experience through the EPRI Neutron Absorbers Users Group (NAUG)
- Potential investigation into realistic estimate of effect of postulated aging effects/degradation on criticality analysis (blistering, pitting, corrosion).
  - Help determine a threshold at which degradation has a negligible/non-negligible effect.

Alternative Proposal

- NEI has proposed the following alternative to the draft Generic Letter:
  - Allow licensees to commit to an acceptable neutron monitoring program (i.e., NEI 12-16)
  - Focus scope of Generic Letter on known susceptible materials (Boraflex, Carborundum/Tetrabor)
  - Exclude the following licensees:
    - No credited absorber in the criticality analysis
    - Already undergone license renewal (have an existing aging management program)
    - Have an approved program in the last five years through a license amendment request.
  - For remainder of plants, remove request for detailed information in Appendix A.

Summary/Conclusions

- Industry has responded to operating experience and NRC notifications to address significant neutron absorber degradation issues. (Boraflex, Carborundum)
- With 35 years of in-pool exposure, Boral continues to provide the same level of neutron absorption capability as when it was installed.
- Newer metal-matrix materials are expected to provide a similar or better level of performance compared to Boral (blistering eliminated).
- Existing monitoring programs and industry research will provide additional information to ensure that any degradation processes are observed and responded to prior to becoming a safety or compliance issue.
- NEI proposed alternative is a risk-informed approach that focuses industry and regulatory attention on those materials that are most susceptible to aging effects and potential degradation mechanisms.