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NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS (ACRS)
SUB-COMMITTEE ON MATERIALS, METALLURGY AND REACTOR FUELS

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TUESDAY,
APRIL 3, 2007

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The meeting was convened in Room T-2B3 of Two White Flint North, 11545 Rockville Pike, Rockville, Maryland, at 8:30 a.m., Dr. J. Sam Armijo, Chairman, presiding.

MEMBERS PRESENT:

J. SAM ARMIJO	Chairman
WILLIAM J. SHACK	ACRS Member
THOMAS S. KRESS	ACRS Member

NRC STAFF PRESENT:

RALPH CARUSO
ANTHONY MENDIOLA
SHIH-LIANG WU
PAUL CLIFFORD
HAROLD SCOTT

ALSO PRESENT:

CARL BEYER

ROBERT MONTGOMERY

ODELLI OZER

GARY DARDEN

NAYEM JAHINGIR

ROB SISK

BURT DUNN

I-N-D-E-X

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

(8:29 a.m.)

CHAIRMAN ARMIJO: The meeting will now come to order. Do we have a -- is that our microphone there? Okay. Great. That's an improvement.

This is a meeting of the Advisory Committee on Reactor Safeguards Subcommittee on Materials, Metallurgy, and Reactor Fuel. I am Sam Armijo, Chairman of the Subcommittee. Subcommittee members in attendance are Bill Shack and Tom Kress.

The purpose of this meeting today is to discuss proposed staff revisions to the Standard Review Plan Section 4.2, "Fuel System Design." The Subcommittee will hear presentations by and hold discussions with the NRC staff, their contractors, and other interested persons regarding these matters.

The Subcommittee will gather information, analyze relevant issues and facts, and formulate proposed positions and actions, as appropriate, for deliberation by the full Committee. Ralph Caruso is the designated federal official for this meeting.

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 March 20, 2007. A transcript of the 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 and volume so that they can be readily heard.

I would also like to remind the Members that the Committee has determined that speakers should be allowed the first ten minutes of the presentation time without questions from the Members. We have received several requests from nuclear industry organizations to make presentations, and they have been included in the agenda for the day.

We will now proceed with the meeting, and I call on Mr. Anthony Mendiola of the staff to begin.

MR. MENDIOLA: Thank you, sir. Good morning, everyone. As a matter of introduction, my name is Anthony Mendiola. I am the brand new Branch Chief for the Nuclear Performance and Code Review Branch.

I've only been in the job about a month and still learning a lot of the things that we're doing and in this case still learning a little bit about the status and the history behind what we've done with Standard Review Plan Section 4.2, "Fuel System Design."

Also, to let you know, I'm also suffering a little bit from the hay fever, so excuse ahead of time if I sniffle and/or my voice changes during the course of the presentation.

The purpose for my part of the presentation today is to introduce my staff, which will be making the majority of the presentation. The staff appears today in front of the Subcommittee to perform an informational briefing, information update on the staff actions thus far with the Standard Review Plan 4.2 updates.

The Standard Review Plan SRP updates were something that we as staff had considered for a period of time but, of course, became much more of an imperative in the last couple of years due to the fact of the goal to have the SRPs updated in time for the COL applicants, which are expected toward the end of this fiscal year and have them in place six months before those applicants came into the NRC with their applications.

The presentation consists of two parts today. The first part, of course, is a detailing of the revisions to SRP Section 4.2, and the second part is a conversation and information associated with the reactivity-initiated accident interim criteria, which is Appendix B of the revised SRP. We will not have a discussion about the changes associated with 50.46(b) except its criteria, as research is still continuing their work on those topics.

The revision to the SRP 4.2 basically is to provide the staff guidance regarding the review of new fuel system designs that have been updated to capture a variety of lessons learned from a variety of sources over the years. These sources are outlined here on the slide, but most of them I'm sure most folks in the room are familiar with.

Industry operating experience, various fuel research programs, and the review of advanced fuel designs and advanced cladding materials have led us to revisit the material in SRP 4.2 and to basically update it from the previous versions. As I mentioned, it became the opportunity to revisit the criteria, and the staff has developed RIA interim criterion guidance to support the new reactor licensing that we expect at the end of this fiscal year.

We've had industry comments. We've received a variety of Industry comments based primarily around the two public workshops that we had at the end of 2006, and I'm certain we'll get additional comments as we get closer and closer to the

COL applications arriving at the NRC.

As I mentioned, SRP Section 4.2 Appendix B specifies new restrictive fuel cladding failure criteria, discusses core coolability criteria and the radiological source term, and presentations later will get into much more detail than I can offer at this point. We are currently finalizing our criterion guidance and will make the necessary revisions to the Reg Guides associated with this part of the SRP.

That's fundamentally just an introduction. I have two staff members that will be making the presentation. The first part of the presentation will be the revision of the actual SRP, and Dr. Shih-Liang Wu will be conducting that part of the presentation, and then when we discuss the RIA interim criteria, Dr. Paul Clifford of my staff will be performing that part of the presentation.

So, beyond that, if there's any questions, I'd like to ask Dr. Wu to come up front.

And for everybody's information, of course, there's handouts in the back of the presentations the staff will be making today.

DR. WU: Good morning. My name is Shih-Liang Wu. I have been working on SRP now for all these years, so is the opportunity for me to present that the new update in our -- the version of the -- the version in March of this year, the updated version.

Let me just start. Now this slide, we're just trying to run down, you know, the history of the SRP, so we start with the July 1981 and then the April 1996 and then the March this year.

So the SRP 4.2 is based on the 1996 version, and then we tried to update, and then as Tony, you know, mentioned earlier that we took this opportunity to update based on the present feelings with the industry lessons learned and research, you know, data and also recent review of the advanced fuel and design and also the new cladding material.

And then I just -- I tried to run through in order a little bit quickly, because this is just a structure that, you know, familiar with, that is familiar with the way we design. You know, all these are straightforward. The SRP is based on -- the structure has design bases, description, and design drawing and the design evaluation. And then design bases has -- you know, there's three category, fuel system damage and the fuel rod failure and the fuel coolability.

And the fuel system damage has -- we

listed eight items now, and from here on, okay, I will only present those we changed. Those I do not present in an item, that means we did not -- either we did not make any changes, or there is little change, which it means little change I mean there is some – there is no significant, you know, technical change.

Okay. So the first item we made change is the oxidation, hydriding and the crud, and now this item is -- in the past, in our old SRP, we only mentioned that you need to consider, you know, thermal effect in the fuel performance, you know, in terms of oxidation, but the current version we talk about a, you know, unspecific limits, and then these limits has to be based on mechanical testing to show, you know, adequate strength and ductility.

Well, let me just say I know we understand that oxidation and the crud is sometimes to difficult to distinguish, so I understand the Industry usually do not, you know, specifically specify how much the oxidation, how much the crud, because there were these measurements, so all these letters I would like to just say early that all these are guidelines. That doesn't means that you're strictly you had distinguished and how much is oxidation, how much the crud.

The next slide shows, you know, dimensional changes, and the same thing. The raw growth and the irradiation growth are old items, and then the third item, the fourth item, that means you can see that this is the PWR recently about just, you know, that recently we just -- our experience showed the channel box can cause in the -- the channel box causing the control plate insertion problem, and then this channel box pole is causing differential irradiation growth, and it showed corrosion and the stress relaxation.

Especially this shadow corrosion is a new phenomenon, and that's the reason that we include it in this. So this is one example we use in -- we call in our industry, you know, experience learned, lesson learned, and so in this case we -- in the number four we said in the PWR we may require in the future, you know, testing of severity to ensure control clad insertion pellet, but actually, my understanding is the Industry already -- you know, BWR Owners' Group has put out they call guidelines for period surveillance.

And then the next item is the rod internal gas pressure. The first -- the number one -- the first one, it says fuel and burnable poison rod internal gas pressure remains below the system pressure. This is a very old criteria.

Now the second one is rod internal pressure is allowed to exceed the system pressure based on these, you know, three conditions: no cladding liftoff and no hydride reorientation and no DNB propagation. And then based on these you can allow it to exceed system pressure, and my understanding is that most industry already, you know, exceed system pressure based on the second, based on these, you know, the criteria on the second item. So this also say, demonstrate that all these, you know, fuel criteria is evolved through all these years.

MEMBER SHACK: But if the old criteria is number one, how do they proceed to number two before you rewrite the guidance?

DR. WU: What is that? I'm sorry, I didn't -- I'm sorry.

MEMBER SHACK: You know, the original guidance is number one that you remain below the system pressure, and yet you've said that, you know, they already routinely exceed the system pressure, although they meet these criterion. Was that reviewed as a separate exception?

DR. WU: Yes. The older fuel vendors, you know, they all supplied topical report to demonstrate when they exceed the system pressure. Of course, now there's a certain limit that you can exceed indefinitely.

There's a certain, you know, a certain limit that not even, you know, vendors, and then so based on the, you know, the topical report, we review them to satisfy all these three conditions, so then we allow them to exceed system pressure.

MEMBER SHACK: Okay, so you're basically systematizing something that you've done under a topical report approval in the past?

DR. WU: Yes. Right. Yes.

CHAIRMAN ARMIJO: What are the limits on the cladding liftoff? I mean, in principle, once you have the internal pressure exceeding the system pressure, there should be cladding liftoff.

DR. WU: No. No, because you are -- the way the system -- in the case of the PWR, 2200 psi. You need to exceed it in quite an amount in order to force in cladding push and forcing the cladding push away from the field, not immediately, right away.

CHAIRMAN ARMIJO: So there's a certain delta-p that's allowable.

DR. WU: Right. Now I think usually the

rod number is about you had to go beyond 700 psi beyond, you know, 2200 psi. Then you're starting --

CHAIRMAN ARMIJO: So around 3,000 psi or something like that?

DR. WU: Yes, is about our range, yes. Yes, that range. Then you starting seeing the cladding starting move away from fuel, yes.

The next item, the control rod reactivity and the insertability, and the first one the people sees old story that, you know, we don't allow it to, to leach away from the cladding, and then the remaining - and the next item 2, 3, 4, and 5 is -- these are the new, okay.

The first one is changing control rod configuration. We meant if you change the, you know, geometry, the shape you change, and the new material, it could be -- we're talking about any that you use new absorbent material, and the next item is changing electronic and the mechanical lifetime.

Now what this means -- this meant that if you, with the current design, and then you're trying to make a control blade, a control rod stay in the, you know, in the reactor a longer time based on some electronic -- based on your electronic, you know, core design or based on some starting mechanical change, then you need to justify it to prolong the lifetime, you know, justify that.

And then the last item is a change in mechanical design is if you -- what it means you're changing the, you know, the basically the strand nature, but I just -- from hindsight we think, you know, the number 2 and number 5 should be, you know, merged together, so this is the thing we can improve in the futures.

Okay, so we're finished with the fuel system damage, and then we go to the second item. It's fuel rod failure, and then here we list is also eight items. The same thing, I'll present only the one we make change.

Now hydriding is in the past we only specify, you know, the internal hydriding. This talk about, you know, fuel rod, I mean, the fuel failure should -- the moisture should be limited, and then we add on external hydriding.

This is kind of new, but I want to emphasize that, you know, emphasize that this external hydriding we did not mean -- we didn't specify the limit. We just think the source of hydriding can be from internally, from internal and also from externally. So in actuality, we didn't specify what is a external hydriding issue considered.

And next one is pellet/cladding interaction, and here is the PCI of it is, you know, we're all familiar with, and then we add on one PCMI, you know, pellet cladding mechanical interaction, and then this PCMI is, you know, strain driven affected, you know, fuel pressure cladding, and then the causing the cracking.

And then the one percent strain limit is still same. The only things we add on that, you know, mechanical testing to show that irradiated cladding remain ductile to sustain the one percent strain limit. This is new, and then we just -- well, this meaning to deal with the high burnup effect that we're concerned that when you go to high burnup, irradiated cladding may not be able to sustain, you know, one percent strain limit. And then the last item, no fuel melting, that's same.

And then bursting, basically this still the same thing, and we based on NUREG--0630, "Cladding Swelling and Rupture Models," and then of the burst you need to consider a flow blockage.

So the last item is new, because when we allow, you know, raw pressure to exceed system pressure, then we start a concern LOCA condition.

Then LOCA accident you could have had, you know, bursting causing the flow blockage. This is our concern during one of our topical review so --

CHAIRMAN ARMIJO: What kind of non-LOCA accident are you concerned about specifically? Just give me an example.

DR. WU: Yes, sure. Paul?

MR. CLIFFORD: Hello. My name is Paul Clifford, NRR. A good example would be the locked rotor event. During that event, the certain number of fuel pins would experience DNB. Clad temperatures would increase, and cladding would creep out due to the rod internal pressure.

DR. WU: So then the next category is fuel coolability, and then there's five items. The first one is cladding embrittlement, and then we didn't change, you know, the others, 2200 and 17% ECR. The third bullet is measuring -- we're planning a rulemaking to implement performance-based acceptance criteria. That's in the near future.

Well, this fuel rod ballooning is the bursting, as we talked earlier, and that's finishing the design bases, and then the one I go to, the right, I mean, the last item is a design evaluation. We made a couple changes.

In the section 3C. Analytical Predictions, we add on cladding collapse and the fission product inventory. Now this cladding collapse is the -- because, you know, we're dealing with a lot of fuel design change, and then some of this cladding collapse was overlooked, you know, with the last one submitted, but the vendor did not or licensee did not really look into the collapse.

Of course, this would not happen, but we just somehow feel that this needed to be emphasized that whatever, you know, your new design, you need to go back to check your old approved code to make sure that your new designs still remain valid for, you know, for this particular cladding collapse analysis.

And then the last item is fission product inventory based on, you know, 10 CFR 100. It's old, and then the new one is -- and this is already in the 10 CFR. It's, you know, 50.34 is for new reactors, and the 50.67 is for existing reactors, and then for non-LOCA accident we even, you know, we allow to use ANS 5.4 model.

I think that finish my talk. Any question? Thank you.

MR. MENDIOLA: Continue on?

CHAIRMAN ARMIJO: Yes.

MR. MENDIOLA: Okay. Honorary Dr. Paul Clifford.

MR. CLIFFORD: Good morning. My name is Paul Clifford. I've been with the staff for about four years. This is my first opportunity to present to the ACRS. Even though I've only been here for four years, I feel like an old-timer with all the new hires.

I always thought it best when making a presentation to answer the fundamental questions, what and why, and we'll get on to how and when. The what is the reactivity-initiated accident. For people in the room that aren't too familiar with it, these events consist of the control rod ejection for the PWRs and the control rod drawbacks for the BWRs.

The next question would be why. Why am I here today? Why has the staff issued interim criteria? And there's really two main reasons why we decided to issue interim criteria for this category of events. The first is for the licensing of the new reactors. We expect many, many COL applications in six months or so, and we felt it was time, and there was a need to develop conservative acceptance criteria and guidance moving forward with this next generation of reactors.

And the second reason was really to provide a good target for the Industry. The Industry will be presenting material later on where they will be discussing the implementation of new criteria for the current operating fleet, and it takes -- it will take time for the Industry to develop the methodology and to develop a strategy for dealing with this much more restrictive criteria, and providing interim criteria gives them a good target.

It's difficult to develop methodology if you don't know what you're shooting for, so we're providing a target for the implementation of the current --

CHAIRMAN ARMIJO: Now to make sure I understand, the interim criteria are intended to apply to new reactors, but when do they get applied to existing reactors, or will they ever?

MR. CLIFFORD: The strategy we have, and I can go to the next slide -- we have a two-stage approach. As mentioned, the interim criteria will apply to the new reactors, all the new reactors that are coming in for licensing, and over the next 18 months we're gonna be doing a more rigorous evaluation of the existing database, and there's also upcoming testing that will hopefully provide us with a lot of valuable information that we can use to potentially rethink and reune this criteria, and we would expect that after 18 months we would be in a position where we would finalize the criteria and guidance.

We would revise Reg Guide 177, Reg Guide 1.183, and Reg Guide 1.195, and at that point we would perform a 5109 backfit analysis and determine the implementation on the current fleet.

CHAIRMAN ARMIJO: Okay.

MR. CLIFFORD: That's really the last slide, so I guess I started at the end.

CHAIRMAN ARMIJO: Yes, but it gives us the whole picture.

MR. CLIFFORD: Right. It's important to recognize as we go through the slides that NRR is building upon Research's fine work in this area. RIL0401 was issued in March of 2007, which provided an assessment of the currently operating units and concluded that there is overly conservative methods being used in the field such that the consequences of an event were it to occur would be acceptable. In fact, they conclude that fuel cladding wouldn't even fail during even the worst postulated accidents.

So we have an operability assessment in our back pocket for the current operating fleet, so that's really one of the main reasons why we feel we can wait the 18 months to then fine-tune them and then implement them to the current fleet.

CHAIRMAN ARMIJO: And you're thinking that that conservatism might not exist in new plants?

MR. CLIFFORD: New plants could have different fuel designs, different rod works. There could be a lot of different fuel management strategies, which could potentially make the event worse. We don't have an analysis for all potential new reactors, so there's really no way of saying that we have time there.

CHAIRMAN ARMIJO: Okay.

MR. CLIFFORD: Yes. The agenda will consist of two distinct areas, and it's always good to identify that there are two distinct areas, because there will be numbers being thrown around today, and people have always gotten confused between 170, 280, 230, 200, and so I broke this up into two.

The first is the radiological consequences. Now this is to satisfy Part 100. To meet Part 100 doses, you need to know two things, how many pins fail and what's the source term from each pin that did fail.

So we are first -- in the first half going to be discussing what is the criteria or the threshold at which fuel cladding fails. Then we will be going on to what is the source term. What is the isotopic population, say, that will be released that will need to go into your dose calculation?

And then secondly and separately, we will be talking about core coolability, and this presentation will deal with meeting the requirements of 10 CFR 50, Appendix A, GDC 28 requirements.

I have a format on these slides I want to make sure that everyone is aware of. Pretty much first I'm going to identify what the current criteria guidance is. Then I'm going to identify what's wrong with it, and then finally I'm going to propose or I'm going to identify what the interim criteria is.

The current criteria for fuel cladding failure is specified in the current SRP, or I guess it was the previous SRP now, and it states that the for BWRs a radial average fuel enthalpy greater than 170 calories per gram would result in cladding failure, and if you exceed your fuel design limits, say DNBR, for instance, then you would have to presume there was cladding failure.

Now the problem with the current criteria is it's based upon testing on very low and sometimes fresh fuel rods, so the effects of high burnup or long residence time and corrosion aren't really taken into effect in the database that supports those current criteria.

The 170 calories per gram is not always adequate to protect rod integrity, and another thing is that the presumption of fuel failure based upon a steady-state critical heat flux correlation may be overly conservative for a transient, which is over in a matter of seconds.

It's important to identify the cladding failure mechanisms, because there are several. The first is the high temperature cladding failure, which consists of post-DNB oxidation and embrittlement and fuel rod ballooning. The second is PCMI, pellet-to-cladding mechanical interaction, and the third would be molten fuel expansion and plastic flow of the -- essentially melting of the cladding.

MEMBER SHACK: Very plastic.

MR. CLIFFORD: Yes, exactly. For the first mechanism, which is the high temperature cladding failure mechanism, this phenomena has been reported in several of the RIA test programs that have been conducted since the 1970s, and it is more limiting than the PCMI failure.

You have fresh fuel that has low corrosion, lots of ductility left in it. Generally that type of fuel can withstand the thermal swelling of the pellet, but you can kind of get bit by going into DNB and dry up.

The sensitivities of this failure mechanism would be anything that affects the heat transfer for the fuel rod and anything that affects rod internal pressure, and it's sensitive to total fuel enthalpy as opposed to a change in fuel enthalpy, which we'll get to.

The next slide here shows the empirical database to date for all of the tests, the reactivity-initiated accident test programs, and here we have the non-PCMI failures.

MEMBER SHACK: Why don't these show some trend with burnup? You know, you tell me your sensitivity is the fact there's the influence -- internal pressure and total fuel enthalpy, and yet I see no -- at least, it looks like a shotgun here against burnup.

MR. CLIFFORD: It would be tremendous burnup effects, because --

MEMBER SHACK: There should be, yes, but I don't --

MR. CLIFFORD: -- because in real life the amount of power you would get from a high burnup rod would be less. In other words, you would have depletion of your fissile materials such that these rods would be less likely to be the limiting rods. However, in these test reactors, remember they're driving the rods to a given power.

CHAIRMAN ARMIJO: I think -- maybe I misunderstood.

MR. CLIFFORD: So it's not like -- you've done an evaluation so that the high burnup rods, all of them would be significantly higher fuel enthalpy in the high burnup, so the low burnup would have high enthalpy, and the high burnup would have low enthalpy. Here they're all driven to a target enthalpy.

CHAIRMAN ARMIJO: But he capability of the material is demonstrated by these tests. It says the material can take -- will not fail by this mechanism until you get to these high enthalpies.

MR. CLIFFORD: Right. This failure is not driven by, for instance, the mechanical properties of the cladding, so the effect of burnup on the cladding doesn't drive this mechanism.

CHAIRMAN ARMIJO: Yes, what's the corrosion failure?

MR. CLIFFORD: It's not a corrosion failure.

CHAIRMAN ARMIJO: What kind of failure is it?

MR. CLIFFORD: It's a DNB failure, or it's a balloon rupture failure. It would be very sensitive to fuel design, assembly design from a DNB perspective, and it would be very sensitive to burnup from a rod internal pressure perspective, because the higher burnup fuel rod would have a higher rod internal pressure, so it has the potential to balloon more readily if it were to achieve high enough temperatures.

MEMBER SHACK: But basically I can drive raw in any of these burnups to this enthalpy is what you're really arguing here.

CHAIRMAN ARMIJO: In the test reactor.

MEMBER SHACK: In the test reactor, and it won't fit, so it has that capability.

MR. CLIFFORD: Right. Here the 170, the red line, that's the current acceptance criteria in the SRP, and I put it up here to illustrate that there are situations where the 170 would not be conservative, and I'll get to those. In these particular cases -- well, we can talk about them now.

These BIGR rods had a high rod internal pressure that exceeded the capsule pressure in the test rig such that once they approached DNB and dryout, they ballooned and failed in that manner, so there is a -- there is some dependency on rod internal pressure.

Here's a figure. I hope it shows up better in your plot. Here's a figure that was provided by EPRI during one of our public workshops, and this is a plot of a lot of NSR low burnup data and the Russian data from BIGR and IGR, and it kind of shows the sensitivity of failure with differential pressure or pressure across the cladding.

We used this information in combination with our own evaluation to come up with our first criteria, and that's the bold criteria here. Essentially, to determine cladding failure due to high cladding temperature failure mechanisms, we've drawn two lines in the sand.

The first one is 170 calories per gram, and that is for any fuel rod where the rod internal pressure is less than system pressure, and the next line in the sand is at 150 calories per gram, and that is to capture the balloon burst effects if you have a rod internal pressure that's high.

The second half of this paragraph states that for intermediate and full-power conditions, there is still the presumption of cladding failure of you go into DNB. So essentially we have an empirically based failure point at zero power, but once you reach power, once you're at power, it's impossible to know -- or I shouldn't say impossible to know.

There is a wide variety of fuel designs and operating conditions, and at any point in the fleet you could fuel designs that are, you know, either this far from DNB or this far from DNB, so it's difficult to say that a certain calorie per gram would cause them to go to dry-out, so there are analytical tools, and there is specific critical heat flux data. Although it's probably a little overly conservative to apply them in this case, it's still conservative, so --

MEMBER KRESS: This database you have on failures, non-failures due to RIAs --

MR. CLIFFORD: Yes, sir.

MEMBER KRESS: -- those come out of burst test reactors, I presume?

MR. CLIFFORD: These are all of the -- this is the test data from the RIA Program.

MEMBER KRESS: Those are test reactors.

MR. CLIFFORD: CABRI.

MEMBER KRESS: Now I presume there's some criteria on the amplitude and the width of the RIA input that has to be mapped in order to be applicable to the real RIA accident. I mean, I could see how you could insert a given amount with a long time and a short amplitude or short time and high amplitude. Is there a criteria for the tests to meet that's based on some sort of concept of --

MR. CLIFFORD: Well, let me start out --

MEMBER KRESS: I would guess the high amplitude/low time would be more severe.

MR. CLIFFORD: Well, for this particular failure mechanism, it's really a total length. It's how much energy you put into the system so that you can go into DNB. A short pulse, a high pulse, would be worse for a clad strain if you wanted to pulse the fuel pellet so that it pushed out on the cladding and potentially failed it that way. Here's it's really total length. It would be over a period of time that causes you to go into DNB. And all of this information here has been presented to the staff.

MEMBER KRESS: That presumes you don't lose much of the heat.

MR. CLIFFORD: Oh, right. Right. There's

all sorts of -- there's all sorts of variables.

MEMBER KRESS: Yes.

MR. CLIFFORD: And each of these tests, as was presented when RIL0401 was presented to the staff, each of these test reactors has different conditions which are non-typical of a power reactor. For instance, some may -- the pulse width could go from -- I think they go from a couple hundred milliseconds to three or four milliseconds, and some are done --

I mean, CABRI was done in a sodium loop, which really doesn't give you a good DNBR relative to water. Some were done in cold conditions. Some we got atmospheric pressure. Some were depressurized, so there's a lot of variables.

CHAIRMAN ARMIJO: These are just raw data. They're not adjusted for system pressure, pulse width --

MR. CLIFFORD: Correct.

CHAIRMAN ARMIJO: -- cladding temperature or anything like that.

MR. CLIFFORD: Correct.

CHAIRMAN ARMIJO: Raw test reactor data.

MR. CLIFFORD: Raw data.

MEMBER KRESS: That may explain -- I was trying to figure out how at a given burnup why there is such a range of impacts in the test, actually.

CHAIRMAN ARMIJO: The open circles are non-failures.

MEMBER KRESS: Oh, yes. I understand that.

CHAIRMAN ARMIJO: I mean, the only things that failed are the filled-in symbols.

MR. CLIFFORD: Correct. Each of the symbols is a different test specimen, so whatever they were targeting for that particular test is what they achieved. In other words, if they targeted a low enthalpy, then maybe they didn't fail, and if they targeted a high one, they failed.

MEMBER KRESS: Well, I was wondering, for example, why the circles in the NSRR test at high burnup never exceeded -- why the test never exceeded the 170. It's probably because they can't get up there, right?

MR. CLIFFORD: It is difficult to get the higher burnup up there. It depends on the -- it depends on the reactor. You know, also, another reason might be that they were targeting a lower enthalpy for the test, because they had seen PCMI failures at a lower enthalpy for the higher burnup rods, so there was -- if you were developing a test, there's no reason to go to 170 if you think it's gonna fail at 70.

MEMBER KRESS: Yes, you're right.

MR. CLIFFORD: As I mentioned, this doesn't have any of the PCMI failure data, though.

MEMBER SHACK: Just on this one --

MR. CLIFFORD: This one?

MEMBER SHACK: -- the previous statement was that up to about 700 psi was, you know, you didn't have to worry too much about this, but that looks pretty generous here.

MR. CLIFFORD: Well, it's really -- okay, during the rod design analysis, you calculate what they call a critical pressure. At normal operating conditions when your clad is only at about 700 degrees Fahrenheit, that's probably the -- 700 to 600 degrees Fahrenheit is where your cladding temperature is going to be.

The critical pressure is going to be 1,000 pounds, roughly, higher than system pressure before you would creep out, and that's based on material strength, clad thickness, you know, fuel rod design. There's a lot of things that influence how strong that tubing is.

Here, as soon as you go -- as soon as you elevate the temperature of that cladding during a transient, all bets are off. Now you're really -- it's the creep properties as opposed to the strength properties that they're going to cause it to swell and burst, so, I mean, that's the difference.

Okay, so we talked about this first bullet, which is the interim criteria for the high cladding temperature failure mechanism, and next we're going to proceed to the PCMI failure criteria.

MEMBER KRESS: Now does this criteria, does is it good for the various new clads that are out there?

MR. CLIFFORD: This criteria is not as sensitive to the material properties of the cladding, because it really is thermal hydraulics, how much heat you get through it before you go into DNB sort of criteria. That's a good question, and it really relates more to PCMI, which is much more reflected by the cladding properties.

Okay. PCMI. We have this. PCMI failure has been reported at many of the RIA test programs, and it's more limited than the high temperature failure mechanism when you start to reach corrosion levels, you know, above a couple cycles of burnup, and it's sensitive to -- it's sensitive to the fuel thermal expansion, anything that will influence the fuel thermal expansion and the cladding material properties, and it's driven by a change in fuel enthalpy as opposed to total fuel enthalpy, and we chose to develop separate lines, separate criteria for BWRs and PWRs, and I'll get to the reasons why.

Here is the data that was -- most of which was presented in RIL0401 back a year and a half, two years ago. We've added a couple points when we've received a couple of points, VA1 and VA2 from NSR, so we've added it to the database. I think there was a couple more, too.

And we drew a line that was similar to what research had drawn in the RIL. The difference between -- I have a slide. Well, let's talk about the data set first before we talk about differences.

We initially anchored the failure criteria to 150 calories per gram. Now that's changed. That's an increase in calories per gram, 150, and that's anchored out to a oxide-to-wall thickness of .04. Now for a modern 17-by-17 PWR design, that's approximately 25 microns of oxide, and how long it takes you to get to 25 microns of oxide depends on coolant temperature and the cladding. Probably cladding has a first-order impact, whether it's, you know, M5, ZIRLO, Zirc-4, whatever it is. It's going to affect the time it takes you to get to 25 microns, and we chose to normalize to wall thickness to account for the large discrepancy in cladding thicknesses in the database.

CHAIRMAN ARMIJO: Why did you use oxide-to-wall thickness for PWRs and hydrogen or hydrides for BWRs? Isn't the mechanism pretty much the same as the embrittling mechanism?

MR. CLIFFORD: The embrittling mechanism is excess hydrogen. It is the hydrides that reside in the cladding, and I can talk about it now. The best approach is to relate the failure point directly to hydrogen.

We didn't have much of the data to support the -- for the PWRs on hydrogen. In other words, when they collected the data, they would have had to have done a test to determine what the hydrogen levels were and they didn't necessarily to all those tests.

Secondly, the hydrogen pick-up fraction and the hydrogen behavior on a PWR is pretty well behaved. There's a lot of data out there for hydrogen corrosion rates and corresponding -- I'm sorry, oxide corrosion rates and corresponding hydrogen pick-up fractions. There's a lot of data out there for PWRs and it's pretty linear. The same can't be said for BWRs.

CHAIRMAN ARMIJO: Okay, so you're comfortable that oxide thickness, wall thickness ratio represents a well behaved hydrogen increase as a function of burnup.

MR. CLIFFORD: I think as we move forward and try to finalize the criteria we're certainly going to investigate that further. There is a large discrepancy between the alloys. In other words, alloy A is going to have a different hydrogen pick-up than alloy B, and that's going to have to be specifically accounted for.

In other words, when a licensee uses this, is going to implement this interim criteria, they're going to have to determine what their corrosion rates are as a function of burnup for their particular unit, and then they're going to have to really cross-compare that to, well, what's their hydrogen pick-up fraction, and how does that differ from potentially the alloys used in developing this line?

That's all going to have to be taken into account, but, I mean, if it was up to me, I would love to find the hydrogen data and re-plot this as a function of hydrogen.

CHAIRMAN ARMIJO: That's ultimately what's the controlling mechanism.

MR. CLIFFORD: Exactly.

CHAIRMAN ARMIJO: Okay.

MR. CLIFFORD: This oxide-to-wall is just a surrogate for hydrogen.

MEMBER KRESS: What's the rationale for the red line having some failures below it?

MR. CLIFFORD: Okay, we drew this line. At the beginning here there's a few NSR points here. There's a PBF. There's one PBF test. Well, first of all, this is a pure empirically based line, and we didn't feel initially that we needed to bound each and every point.

MEMBER KRESS: Why not?

MR. CLIFFORD: Why not? Well, there was a lot of non-prototypical conditions that are in this test and certain points that are more questionable as far as their applicability to the current fleet.

MEMBER KRESS: I gather from that you can take every one of those points below it and point out some reason why you can ignore it or discount it?

MR. CLIFFORD: I wouldn't say we would ignore each point. It gets a little dangerous when you start throwing away, when you have such a limited database, when you start throwing away points, but, for instance, the NSRR, which is the circles, the dark circles, those were slightly adjusted following what the real methodology was, the RIL0401.

However, there's an expectation that there is new data becoming available in the next 12 months where the NSRR is going to be running hot tests. These are all done at room temperature, 20 degrees Celsius, and temperature has a more first-order impact on cladding properties and ductility, and so it would have a first-order impact on PCMI failure, and we expect that when we see the results of the hot cell program that we're going to be able to -- in addition to putting more dots on the figure, we're going to be able to calibrate or recalibrate those dots such that they'll be above the line. So knowing that we had this coming, we didn't want to be overly conservative.

MEMBER KRESS: The CABRI tests, those are the ones you said were sodium-cooled?

MR. CLIFFORD: CABRI is sodium-cooled, but they are --

MEMBER KRESS: That's a reason for maybe discounting those diamonds?

MR. CLIFFORD: Well, for a pure PCMI failure, the sodium bursts the water. It shouldn't have that much of an impact. Certainly it had an enormous impact on high temperature cladding failures because of the heat transfer, the tremendous heat transfer of sodium versus water, but for a pure PCMI failure it should be less.

Now there will be more data when it comes out in, oh, two years, three years, because CABRI is supposed to be converting their loop to a water loop such that they'll give us data that's more typical.

MEMBER KRESS: Is that red line slanted above .08?

MR. CLIFFORD: .08 was one of the anchor points.

MEMBER SHACK: But it has a slope is what he's saying.

MEMBER KRESS: That seems a little strange for empirical data of this type. I would have had that a straight line. I can't envision the reason.

MEMBER SHACK: Where do you put the elbow in what you picked for the slope?

MEMBER KRESS: Yes, those are questions I would have about it, but --

MR. CLIFFORD: I think if I gave a raw plot like this to everybody here, we would end up with --

MEMBER KRESS: You'd end up with different --

MR. CLIFFORD: -- 45 different slopes.

MEMBER KRESS: You certainly would, yes.

CHAIRMAN ARMIJO: Now these are all for cold tests, all of these data are.

MR. CLIFFORD: Not all of these data are for cold tests.

CHAIRMAN ARMIJO: All the NSRR?

MR. CLIFFORD: Correct.

CHAIRMAN ARMIJO: Now if you go up to higher temperatures, the expected cladding temperature in a reactor, the hydrogen goes into solution. At least part of it reads off.

MR. CLIFFORD: Part of it, about 100 ppm or so.

CHAIRMAN ARMIJO: And how big an effect would you expect just from that?

MR. CLIFFORD: Well, the -- I think the solubility of hydrogen at normal operating temperature is around 100 ppm, and that corresponds to -- in very clad allow dependent, but for, say Zirc-4 it's probably about 25 microns. What do you guys think over there? Good guess? Say 25 microns, so up to 25 microns, which is approximately this -- where the 150 before it drops down. You would essentially have no hydrides. They would all be in a solution.

MEMBER SHACK: So that accounts for the

flat part of your curves then.

MR. CLIFFORD: Right.

MEMBER SHACK: And after that you're exceeding the solubility, and so you're --

MR. CLIFFORD: Right. Now we're going to get into -- when we get to BWRs, we're going to talk about that very point, because the BWRs, they can be at cold conditions when they start up.

CHAIRMAN ARMIJO: Right. I understand that.

MR. CLIFFORD: So they have to take that specifically into account.

CHAIRMAN ARMIJO: Right. Right.

MR. CLIFFORD: And I'll get to that in the next slide or the next two slides, but this is the reinforced, what we see here in the next slide. Here is a comparison of the PCMI failures. The dotted line, the blue dotted line -- excuse me -- the blue dotted line is that of RIL0401.

MEMBER KRESS: So you're telling the Research people that we don't believe that restrictive is necessary?

MR. CLIFFORD: I would never say that. No, the difference between the blue dotted line and the red line is really that took a nose dive right at the beginning, because it wanted to bomb some cold NSRR data points that were on BWR Zirc-2 cladding, so the difference we have here is we removed all the BWR Zirc-2 cladding from the PWR.

MEMBER KRESS: Oh, those are BWR data?

MR. CLIFFORD: Yes.

MEMBER KRESS: That shows on the previous?

MR. CLIFFORD: No, no, no, no, no. The previous slide is all PWR data, but --

MEMBER KRESS: Well, it looked to me like they were trying to --

MR. CLIFFORD: If you would put the -- if you go back and look at the RIL, there's a bunch of data points here.

MEMBER KRESS: I see.

MR. CLIFFORD: And these are BWR data.

CHAIRMAN ARMIJO: You can't talk away from the mic.

MR. CLIFFORD: I can't hear myself in this.

MEMBER KRESS: Just don't write on the screen with the pen.

MR. CLIFFORD: It'll burn a hole in it. Right here in the RIL there were several BWR Zirc-2 samples that were used in determining this line, and by removing that cluster of BWR Zirc-2 when determining the PWR line, it allowed us to move that up.

Also, there were a lot of testing up above this area that didn't show any failures. We haven't seen a lot of or any failures when you had essentially no corrosion and no hydrides. The cladding is very ductile at that point, and it's able to withstand that.

So here is the RIL0401, and here is my projected line. As you can see, they're very similar when they get out to this point here. The dotted line is something that EPRI will be discussing later on, and this, whereas these two lines are purely empirically based -- in other words, you look at the empirical data. Maybe you perform a little scaling, whatever you feel comfortable with, but you go with an empirical limit.

The dotted line represents a mechanistic approach. Separate effects testing is used to a mechanistic model, which is then used to determine the point of failure, and they'll be presenting later on that they believe that the points that I used to bring this down here, the points right -- this family of points here, they believe they can be either further adjusted, or they can be dispositioned somehow, so they don't need to include them, and they've got valid -- they've got some valid points, which you'll like to hear, but we end up similar out here.

So the purpose of this slide is to show that we do deviate from what Research presented us with, but there's a reason for that, and even though we're using what we feel a pretty conservative approach, we don't differ that significantly from what the Industry is proposing, and for an interim criteria, you always want to err on the conservative side.

MEMBER SHACK: Good writeup, because this is in two colors which are absolutely indistinguishable in my screen.

MR. CLIFFORD: What this slide represents is the application of a corrosion-based criteria in the field. In other words, to give a licensee or a fuel designer corrosion-based criteria isn't really useful, so they're going to have to convert that corrosion-based criteria to a burnup-dependent criteria, and they'll do that by evaluating hydrogen pick-up percentage and their corrosion behavior, their cladding at their operating temperatures, and they'll come up with a different curve.

Here is two different curves. This would be -- this would be a modern alloy like optimized ZIRLO or M5 here where you have good corrosion properties such that you're really not getting a lot of oxide, and you're really not picking up a lot of hydrogen, so you're not really paying the penalty of it, whereas this would be more of a current Zirc-4.

CHAIRMAN ARMIJO: Now with your interim criteria, do they get credit for use of the modern material that doesn't pick up much hydrogen?

MR. CLIFFORD: Absolutely. Absolutely they would be able to take that.

MR. CARUSO: Is that staff going to require licensees to monitor oxidation film thicknesses in order to verify that the fuel is performing as modeled?

MR. CLIFFORD: That's a good question. We generally already have approved corrosion models built into the fuel performance analysis where they've presented a lot of pool-side examinations where they've done corrosion measurements, and then in combination with out-of-cell hydrogen measurements, there's enough data presented. Do I expect to see a change over time? There should be enough information, but because there's so much operating experience with like a Zirc-4 --

MR. CARUSO: There's also some operating experience with surprises that have occurred because people didn't control their chemistry.

MR. CLIFFORD: Well, certainly crud and the effect of crud on corrosion is a wild card.

MR. CARUSO: So is the staff going to require people to monitor their corrosion every refueling outage to verify that the fuel is oxidizing as the model is expected to oxidize, or are you just going to be faith-based and --

MR. CLIFFORD: It's a good question.

CHAIRMAN ARMIJO: It would be pretty impractical, I mean, to try and do it to that level. You've got to have some level of confidence that the database and the materials are well controlled.

MR. CARUSO: Some countries do that.

MR. CLIFFORD: Well, I think a problem, a visit would probably be sufficient to identify whether you had a crud problem.

CHAIRMAN ARMIJO: Or if oxide's falling or something bad going on.

MR. CLIFFORD: Right, but to go in there and take any current testing or any other means each cycle, that would be -- that would add time to the reloads, and we would get a lot of resistance on that.

This I'm sure they would agree with.

CHAIRMAN ARMIJO: Okay. Well, this encourages the development and application of modern materials that address the hydrogen embrittlement issue.

MR. CLIFFORD: Absolutely.

CHAIRMAN ARMIJO: And they would get -- they'd have a benefit if they applied that using these criteria.

MR. CLIFFORD: Right. The Industry, when the Industry first came in, they proposed criteria where they did the conversion themselves using worst case Zirc-4, and I thought that was too much of a hit, you know, to not be able to take advantage of a modern cladding alloy.

Okay, next we come to BWR, and as I mentioned, we separated the BWR Zirc-2 NSR data from the rest of the population, and we looked at it as a subset, and here it's plotted with reported hydrogen content, which is the first-order effect on ductility, cladding ductility, and there's some uncertainty in hydrogen measurements and variability of hydrogen content in a given specimen, and that's represented by these little dumbbells or whatever you want to call them.

And so once again we maintained 150 calories per gram, which is -- we chose 150, even though we didn't see a lot of failures above that, even that, because that corresponds to the 170 that we're proposing for the high temperature. If you take the 170 high cladding temperature failure line, adjust it for the fact that at hot zero power you could be at 20 calories per gram, you're at 150, so you can't -- even though you could have drawn this line, potentially drawing it higher, it doesn't buy you anything, because you're going to be limited by the other failure mechanism, so there's no sense even drawing it differently.

CHAIRMAN ARMIJO: What's the approximate burnup for a modern Zirc-2 at the 150, you know, at the knee of that curve, the 150 ppm hydrogen?

MR. CLIFFORD: That's a good question, and the reason -- well, we wanted to go to hydrogen content, because it is a first-order impact.

CHAIRMAN ARMIJO: Sure.

MR. CLIFFORD: But the need to go to hydrogen for BWRs was that it is a shotgun when you look at hydrogen content as a function of burnup and hydrogen content even as a function of corrosion. There is a wide variability, so, you know, when developing the criteria, we really felt like we needed to go right to the source, which was hydrogen, and 150 ppm, I mean, I would guess that that would be relatively high burnup. I would guess that that would be 40,000, 50,000 burnup. Guys, you got any input on that?

CHAIRMAN ARMIJO: With that much variability, what will the BWR people have to bring you to satisfy you that they know what their hydrogen is as a function of burnup for a particular fuel design?

MR. CLIFFORD: Because it's less well behaved, they're going to have to provide us with a sufficient database of hydrogen content as a function of burnup and then for them to then do that conversion to a useful tool, and depending on the spread of the data, I mean, you may be forced -- instead of using a best estimate, you may have to take like a one sigma or something. It just depends on the variability.

CHAIRMAN ARMIJO: Thank you.

MR. CLIFFORD: Okay, so the light one we talked about earlier. Here we have the two PCMI failure criterias. One is a function of function of oxide-to-wall thickness. One is a function of hydrogen, and those were put into the SRP update.

Now next we get to -- well, now we have new criteria, which are more restrictive for determining when cladding fails. Well, we also looked at what about the fission product inventory. In other words, how much iodine is there in the -- or xenon is there in the gap, or how much iodine is there available for release if you do fail the fuel?

The current criteria is 10 CFR Part 100, and the guidance for that is in Reg Guide 77, which identifies the off-site doses must be within -- must be well within.

MEMBER SHACK: Is that a factor of three?

MR. CLIFFORD: Oh, well within. I don't know who created this, but there's some secret decoder ring out there. Small fraction is equivalent to ten percent of the allowable doses. Well within is equivalent to 25 percent of the allowable doses, so 300 rem would go down -- which is the 100 percent of 10 CFR for, what's that, inhalation, two-hour inhalation thyroid dose? Go from 300 down to 75.

The guidance on calculating doses is in Appendix B of RG 1.77, and it's also in newer Reg Guides. It's in Reg Guide 1.183 and Reg Guide 1.195, and they all say roughly the same thing, that you should assume that ten percent of your iodines and ten percent of your nobles are present in your plenum region of your fuel rod such that if you have a breach in your cladding, that inventory is available for release and must be accounted for specifically in dose calculations.

The problem with that guidance is that there's been a lot of fission gas measurements following these test programs. They would take a test that didn't fail, and they would go and do a puncture test and measure the isotopic population that was released, and what they noted is there's a lot of fission gas there, and --

CHAIRMAN ARMIJO: More than these ten percents?

MR. CLIFFORD: Right.

CHAIRMAN ARMIJO: Oh, okay.

MR. CLIFFORD: So you need to take that into account, and what we have here, we first have to look into the mechanisms. What's going on inside the fuel room? Even though the cladding doesn't fail, what's going on in there?

What's happening is over normal, routine operation, you get a diffusion of fission gas, fission products along the grain boundaries, out into the plenum, and that is really a function of diffusion and time and power and power history if you go through some various power ramping, whatever you're maneuvering, moving control blades, whatever you're doing that can cause that diffusion to change.

But during this particular transient, during this .05 seconds, what you can see is the pellet itself is going through a very dramatic transient. It's cracking. It's breaking. There is grain boundary separation, and during that violent transient, the pellet is releasing more fission gas.

I'm going to call that transient fission gas release, and this transient fission gas release is strongly depending on how much power that pellet sees. It's strongly dependent on local power, and there's also -- there would be potentially some burnup effects, how much fission gas is available, and we've looked at -- let me just jump right to the --

We've looked at all of this data, and we looked at it as a function of pulse width. We looked at it as a function of burnup. We looked at it as a function of anything we could think of, and this was the best correlation we could come up with.

There is -- all of this data represents measured fission gas release, and if you plot it as a function of the change in enthalpy that the specimen saw, you see a pretty good correlation. In other words, if you put 100 calories per gram change on a fuel pellet, it's going to release somewhere around 15 percent of its fission gas in addition to what may have resided in the plenum region before the transient even started, so both of these factors need to be combined to get your overall source term for your dose calculation.

I think these points here -- if memory serves me correctly, I believe that these points here were high enrichment, and by high I mean above five percent, and these were research reactor fuel rods from Japan.

CHAIRMAN ARMIJO: So those weren't really BWR?

MR. BEYER: No, they were commercial reactor, but they might have been around five percent. I can't recall the exact enrichment level, but they might have been around five, but one thing you can say about them is that they were of a different fuel type than a lot of the points up there except for there's a couple of points that are below the line that had that same fuel type, so we're a little bit --

CHAIRMAN ARMIJO: There's a lot of variability there.

MR. BEYER: Yes, right, and those three data points all came from one rod. Those came from small sections cut from the same rod, and for some reason they behaved significantly different than all the rest of the data. We've got like, I don't know, 33 data points up there, and --

CHAIRMAN ARMIJO: Were these prefabricated test panels?

MR. BEYER: Yes, they were prefabricated, right.

CHAIRMAN ARMIJO: Yes, so a lot depends on how --

MR. BEYER: Yes, theoretically you could think about cracking due to refabrication of the fuel, but a lot of these data points up there are prefabricated, too, so, you know, you could argue that that may not explain it, either, and it's kind of -- Robbie, do you have any opinion on those three data points, because I know Industry has looked at this, too.

MR. MONTGOMERY: Robert Montgomery from Anatech. No, those three rods, which, like you said, come from this come from the same father rod, do kind of seem to be outliers in a way. They show a unique behavior relative to all the data.

They were fabricated with a different pellet fabrication process than most of the other data out there on that plot. It had to do with the type of grain structure and things in that nature that could affect the distribution of the fission gas in the pellet. These had an interesting rem size variation, so there may have been a different fission gas inventory in the rem, which sees the largest amount of temperature and the largest cracking in the pellet.

CHAIRMAN ARMIJO: Okay, so you've just tended to discount those data points and say the line represents the envelope or bounding --

MR. CLIFFORD: Well, I think, even if you were to include those, you still want to fit the data, and I think you would end up with pretty much the same line.

MEMBER KRESS: This is just the transient release in addition to the gap?

MR. CLIFFORD: Exactly.

MEMBER KRESS: These tests had the gap inventory removed before you --

MR. CLIFFORD: Well, for many of the tests, I mean, when you manufacture the specimen, you know, when you're cutting, you're removing the fission, whatever was there during the whole operation, so anything you measure would be a product of the transient, unless you had a segmented rod that was in a reactor, which -- any of these actual segmented rods that were radiated as specimen?

MR. BEYER: I can't remember if any of them are segmented or not, but if they were segmented, typically they usually had relatively small gas release.

MEMBER KRESS: Were the clads purposely failed in these tests?

MR. CLIFFORD: No, none of these are failed.

MR. BEYER: No, all these were -- yeah.

MEMBER KRESS: Well, then how did you get any release if they didn't fail?

MR. CLIFFORD: Well, I think what we're showing is just the pulse, the power pulse on the pellet itself. Whether that was enough to cause cladding failure or not, it still resulted in -- it was insufficient.

MEMBER SHACK: It's measuring the plenum.

MR. CLIFFORD: Yes.

MEMBER KRESS: Measuring the plenum.

MR. CLIFFORD: Oh, I'm sorry, yes.

MEMBER SHACK: They didn't release it.

MEMBER KRESS: Okay, now I understand. So essentially you remove the original gap inventory, and then you measure what gets in the plenum due to a --

MR. CLIFFORD: That's correct.

MEMBER SHACK: This pulse.

MR. CLIFFORD: Right, so the guidance we're providing is essentially that you would need to combine the two effects, the steady state inventory that would be there during the normal operation and a calculated transient fission gas release, which we provided this correlation.

MEMBER KRESS: And this is not a function of burnup, or the burnup shows up in the database?

MR. CLIFFORD: We looked at it as a function. I would have expected a much stronger burnup dependence only because you have more fission gas that's in your grain boundaries to start with, so it wouldn't take as much of a pulse to --

MEMBER KRESS: And you've got the -- and you've probably got more damaged fuel, more surfaces, more rem effects.

MR. CLIFFORD: Right, exactly, but it didn't fit as well as just looking at power.

MEMBER SHACK: And you really tried looking at both of them? You know, you seem to have this tendency to look at one variable at a time, but, I mean, if you looked at the two of them, it didn't -- you know, burnup and enthalpy rather than, you know, well, enthalpy is better then burnup but --

MR. BEYER: Well, what we --

MR. CLIFFORD: We tried looking at this, but then breaking it up to coloring and, like, between zero and 30 burnup, 30 and 40 burnup, 40 and 50 burnup and then --

MR. BEYER: Yes, what we did is we'd apply this correlation here just for the power effect and then plot it as burnup then and see if we could see, and in some instances a few tests looked like they were a burnup dependence, and others didn't look like there was any burnup dependent, so there was a lot of scatter in the burnup effect.

MR. CLIFFORD: In the technical basis document for the SRP updates there's a log there if you guys want to come take a look at this.

MEMBER SHACK: Is this the one that gets buried in the pdf file?

MR. CLIFFORD: Here, this shows -- this is for --

MEMBER SHACK: Yes, and that's a different one.

MR. CLIFFORD: Maybe I don't have it in here. I have a spreadsheet with tons and tons of plots. This is fission gas for these versus pulse width, the fission gas for these versus burnup.

MEMBER SHACK: Yes, but see, you need to do what Carl suggested, which was to, you know, that way you're hiding the enthalpy in that plot.

MR. CLIFFORD: Right.

MEMBER SHACK: What you need is to do the enthalpy and then plot it against the --

CHAIRMAN ARMIJO: Color code them or something for the burnups.

MEMBER SHACK: -- and see how they bounce up and down.

MR. BEYER: We've done that, too.

MR. CLIFFORD: We've done that. We've done that, and then we decided there wasn't as much of a printer. During the break -- I'm sure I have the spreadsheet on my disk. I could get that and check following the break.

Okay, so ultimately we're saying that there is another effect on fission gas release that's not currently accounted for and needs to be.

CHAIRMAN ARMIJO: How do you know that if you tested, let's say, segmented rods, already had some fission gas release, already have poisoned the gap and if -- well, how do you know that that wouldn't actually make your transient fission gas release during an RIA even worse?

MR. BEYER: Because it's not a thermal effect.

CHAIRMAN ARMIJO: You're just saying this is just a shattering of the pellet? It's not a temperature change?

MR. CLIFFORD: It's not diffusion-related. It's not time and temperature. It's instantaneous.

CHAIRMAN ARMIJO: Two separate mechanisms?

MR. CLIFFORD: Right.

CHAIRMAN ARMIJO: Okay.

MEMBER KRESS: It looks like a substantial effect. You get up to 30 percent of the inventory. You really, I mean, yes --

CHAIRMAN ARMIJO: If you take a sledge hammer and smash into it, it's going to come out.

MEMBER KRESS: But the containment's still intact.

MR. CLIFFORD: Absolutely.

MEMBER KRESS: So you compare these numbers and see how far 100 to --

MR. CLIFFORD: Dose is usually not

limiting. Offsite dose is usually not limiting to the this event.

MEMBER KRESS: Yes, I would guess not, because normally 10 CFR 100 asks for inventories much bigger than this to be put into containment.

MR. CLIFFORD: Well, you could consider, even though your acceptance criteria is one-fourth that of LOCA, the LOCA source here you dump the entire core, assuming that the whole -- you have 100 percent of your nobles and 50 percent of your iodides all just dumped into containment.

MEMBER KRESS: Yes, that's in the containment.

MR. CLIFFORD: And you survive that.

MEMBER KRESS: Yes.

MR. CLIFFORD: Even though your release path is a little different, and your acceptance criteria is lower, the inventory is significantly lower than that of a LOCA, and also, it's a localized event. The troja injection is a very localized event. You're only going to have so many pins in that region of the core that's going to get out.

MEMBER KRESS: Oh, yes, this -- you have to count the number of pins.

MR. CLIFFORD: You've got to count the

number of pins. This isn't core-wide. This is the number -- this is the fission gas in a particular pin, so if you only take six --

MEMBER KRESS: Yes, that can make a big difference.

MR. CLIFFORD: If you only fail 1,000 pins out of 50,000 pins, you can see that the source term still isn't --

MEMBER KRESS: Yes, it's not really. Yes, I've got you.

MR. CLIFFORD: Okay. That concludes the first half of the presentation on calculating the number of pins that fail and what's the source term for your dose calculation. Next we're going to get into the long-term cooling, which is GDC28, and the reactive vessel integrity concerns.

CHAIRMAN ARMIJO: You've got about ten slides, and we could -- we're ahead of schedule. We could take a break now. It's ten minutes of 10:00, so let's get back about five after 10:00, you know, a 15-minute break, 10:05.

MEMBER KRESS: Which clock are you going by?

CHAIRMAN ARMIJO: The official wall clock. I have their -- well, you're right.

MEMBER KRESS: Ten after.

CHAIRMAN ARMIJO: Ten after 10:00. We'll recess for now.

(Whereupon, the foregoing matter went off the record at 9:52 a.m. and resumed at 10:11 a.m.)

CHAIRMAN ARMIJO: Okay. We are resuming the meeting, and if we can find Mr. Clifford -- okay. All right. We're ready to resume.

MR. CLIFFORD: Right. What I pulled up here during the break was this is just a plot of the same data, and, as we were talking about, we wanted to see if there was a burnup dependence. Here we have the CABRI test data. Fission gas release is a function of peak fuel enthalpy, and then we have three different groupings, and it's similar down here with the NSRR how we have two different groupings because most of the fuel is likely it's going to burn up.

And we looked at this and decided, well, you know, is it potentially two lines? Could there be a line here and a line here based on burnup? And we really didn't see it, so what we chose to do was to group them all together and to kind of not bound all the data but from the previous slide -- let me get back. That's not it.

In the previous slide, we didn't bound all the data, but we put it all into one population, and then we put a line about a majority of the data, I'd say. It's not a best estimate fit. I wouldn't call it a one sigma, either.

MEMBER KRESS: You know, that all brings to mind the question. You know, the obvious choices are either a best estimate fit or a bound, and anything that's different from those needs explaining, at least it does in my mind, and so I don't understand. I don't understand the line. I understand that a line is a good thing to have there, but why not a binding line or --

MR. BEYER: Well, what we did here is originally we did have a best estimate line for UO_2, and then we had one for MOX. The MOX one was a little bit higher than the UO_2 one, and for the RIA, NRR just decided to take the upper bound for MOX and use that one.

MEMBER KRESS: The line is an upper bound for MOX?

MR. BEYER: No, it's a best estimate for MOX. It's a best estimate for MOX.

MEMBER KRESS: It's a best estimate for MOX.

MR. CLIFFORD: It's a best estimate for

MOX, but it's not that significantly different than the best estimate fit for the UO_2.

MR. BEYER: For the UO_2, right.

MR. CLIFFORD: So you just combine all fo the data into one population and just choose which line is a little more conservative.

CHAIRMAN ARMIJO: This is -- when you say best estimate, is this just a least squares fit?

MR. CLIFFORD: That's all it was.

MR. BEYER: Correct. Correct. Right. Right, and it was a best estimate fit through the MOX data, and the UO_2 one was a little bit lower, but not significantly lower.

MR. CLIFFORD: I think it's the -- can you see? The pink, I believe, is the MOX, that data point, that data point.

MR. BEYER: Correct.

MR. CLIFFORD: It's those two.

MR. BEYER: Yes, that's it, just two data points.

MR. CLIFFORD: Those are the data points.

CHAIRMAN ARMIJO: Okay.

MEMBER KRESS: Two data points --

MR. BEYER: Yes. Right.

MEMBER KRESS: -- out of --

MR. CLIFFORD: Let's make a line.

MEMBER KRESS: Connect the two.

MR. BEYER: Right. Right.

CHAIRMAN ARMIJO: You ought to -- you should have gone through zero and those three points.

MR. BEYER: Yes, but the UO_2 one was slightly below that for best estimate, and, yes, and surprisingly they were both parallel together, reasonably parallel. The UO_2 best obviously has a lot more data and, you know.

MR. CLIFFORD: But I would say since we added that last grouping of data as it became available, there used to be a difference between the UO_2 best fit and the MOX best fit, but that almost disappeared when we added this grouping up here.

MR. BEYER: Correct. Correct, yes.

MR. CLIFFORD: Over the next 18 months we're going to try to obtain further data and fine tune this correlation.

MEMBER KRESS: I think you need a rationale for why best estimate is appropriate for this kind of regulation as opposed to bounding, and, you know, normally conservative people use bounding approaches.

MR. BEYER: Well, you could add another four percent or so to this line, and it would be essentially bounding.

MEMBER KRESS: Yes, it's not that it would make enough of a difference to make me worry about it. In fact, the whole release amount is not enough to make me worry too much about it, but, you know --

MR. BEYER: But technically for a good argument, huh?

MEMBER KRESS: -- you need a technical rationale to it.

MEMBER SHACK: Except there is no such thing as bounding. You can only bound the data, but --

MEMBER KRESS: I know, so no matter what you do, you'll probably have some confidence level in it.

MR. CLIFFORD: Okay. The second of the presentation we'll be dealing with coolability and reactor vessel integrity, which, once again, is the requirements to meet GDC28.

The phenomena at play during this particular category of accidents is such that you need to worry about a pressure pulse being generated by the interaction between the fuel, either molten or near molten fear fragments as they're expelled into the reactor coolant.

Essentially, there is flow blockage due to fission product-induced swelling of the fuel coupled with cladding plastic deformation, fuel pellet and cladding fragmentation and dispersal, and fuel rod ballooning. These are the four phenomena that could effect either long-term cooling or reactor vessel integrity.

Here is a -- I wrote down what GDC 28 states. Basically it says that you cannot exceed limited local yielding on your active pressure boundary, and you must maintain core cooling capability, and that regulation is disseminated within Reg Guide 1.77, which defines the acceptance criteria to meet GDC28, which states that the radial average fuel at the beam must be less than 280 calories per gram and that the maximum reactor pressure boundary pressure cannot exceed Service Level C, which is approximately 120 percent of design.

Now what's wrong with the current criteria? As early as 1980, an evaluation was done by a gentleman named MacDonald and friends, who did an evaluation of the SPERT, TREAT and then recent PBF test results, and he concluded that if you were to subject a fuel rod to the 280 calorie per gram limit that there was a good probability that you would lose your fuel rod geometry and impair long-term cooling capabilities, and had the NRC expressed the criteria in fuel enthalpy versus total deposited energy, the more appropriate limit would have been 230 calories per gram. In addition, fuel fragmentation and dispersal is not addressed, and fuel rod ballooning is not addressed.

So what this slide states is that the 280 calories per gram is wrong. MacDonald, back in 1980, determined that 230 was a more appropriate limit and that there's other aspects of long-term cooling that also need to be addressed that aren't part of the current guidance.

The empirical database for loss of rod geometry and molten fuel coolant interaction is based upon SPERT and PBF test programs. The more recent tests that were conducted in Europe and in Russia didn't necessarily target a deposited energy which would result in molten fuel.

They were targeting, determining the point of clad failure, not the point of fuel melt. And fuel fragmentation and dispersal has been reported at several of these test programs. In addition, pressure pulses have been measured at several of these test programs.

The staff has developed four interim criteria. We'll first discuss the first two, which is the first one is that radial average fuel enthalpy must remain below 230 calories per gram, and this is based on the 1980 finding by MacDonald, which is an evaluation of SPERT, TREAT, and PBF. And the second criteria is that fuel temperatures must remain below incipient melt conditions, and the next slide shows you graphically what this means.

The upper line here, the black, is the current criteria, 280 calories per gram. The blue line is what MacDonald proposed based on an evaluation of the empirical data at the time. That's 230 calories per gram, and the green I have two calculations of fuel melt temperatures. One's at a 20 millisecond pulse width. One's at a 10 millisecond pulse width.

What you should take away from this slide is MacDonald observed that you could lose coolable geometry potentially below melting conditions, and also melting -- the enthalpy required to achieve melting temperatures reduces significantly with burnup, and that's due to a decrease in conductivity, fuel conductivity with burnup. That's due to a highly edged pellet power distribution during the transient in the rim region, and that's also due to a very high burnup distribution in the rim region, which reduces your melting point.

So the criteria from one and two combined would be the lower of these lines, and it would be expected that this line here, these green lines, would be dependent on fuel design. So instead of trying to come up with a single line, we would allow the Industry to calculate using their specific fuel design what their enthalpy is to achieve melt temperatures, and that would be determined and submitted and reviewed.

CHAIRMAN ARMIJO: Now the coolable geometry in the low burnup range, is that ballooning? Is that the issue there, yes, right in that region, the MacDonald?

MR. CLIFFORD: This line here?

CHAIRMAN ARMIJO: Yes.

MR. CLIFFORD: MacDonald concluded that you could, as you approach melting conditions, you can have all of the fission product swelling, which can result in cladding. He called it a loss of rod geometry. Essentially your cladding started to melt and flow plastically into the channels, so you had a situation where you didn't have a rod type geometry, so you couldn't guarantee cooling, in other words, if this was to happen in a large region of the core.

CHAIRMAN ARMIJO: Okay, so it's literally clad melting is the phenomenon that he's concerned about.

MR. CLIFFORD: Right. When it's below, yes. If it's at fuel melting, of course, when you get fuel melting you get a volumetric expansion. You get the fuel-coolant interaction and then an expansion of the molten fuel into the channel, but --

MEMBER KRESS: This presumes a fixed value for the melting temperature of UO_2?

MR. CLIFFORD: No. This would be calculated assuming -- this is a localized calculation. In other words, at a higher burnup, the local burnup in the rim region would be significantly higher, maybe a factor of two or three higher than the average pellet burnup.

So say you're at 50,000 pellet average burnup. You could be at 100,000 burnup, local burnup in your rim region, so you would have to include the decrease in burnup temperature with burnup at that local area, and then you would also have to take into account the tremendous edge power shape during the transient.

MEMBER KRESS: Of course, that's how you calculate it. My question was do you assume UO_2 has one melting temperature?

MR. CLIFFORD: No. It's burnup-dependent. It's also dependent on other additives, but it's burnup-dependent, 5080 minus, what is it, 60 per every ten megawatts, something like that?

MEMBER KRESS: It this because you're building in more plutonium and more fission products, and it changes the character of the UO_2?

MR. CLIFFORD: Absolutely. That has to be taken into account. That's the first two criteria, and those criteria are more -- what's the word I'm looking for? Those two criteria's numerical value, it's very specific what it is. You calculate what your fuel enthalpy is for your particular fuel design to reach melting temperatures, and you have your two 280, I'm sorry, your 230 ceiling.

The next two criteria are really to account for the effect of fuel coolant interaction. Now we've already said there can't be molten fuel in item 2, but there's still a potential to disburse finely fragmented fuel particles that are approaching melting temperatures, and the energy deposition or the mechanical energy conversion of that dispersal needs to be accounted for in your pressure calculation. You still can't exceed -- you don't want to blow apart your reactor vessel. You have limits on pressure, and you have to specifically account for the pressure pulse generated by the dispersal of non-molten fuel, and --

MEMBER KRESS: That means you have to know how much fuel gets dispersed and what the heat transfer mechanism is and what the particle sizes are and things like that?

MR. CLIFFORD: Yes. I'll get to that in the next slide. This area of the criteria is a little more difficult to respond to, and the database for fuel mechanical interaction is somewhat limited, and we believe it needs to be accounted for, and the staff is basically drawing a map, saying "Here are the type of phenomena that have to be addressed, and we're awaiting the Industry's response."

The fourth criteria is addressing the effects of fuel pellet fragmentation and dispersal and ballooning. This would be more flow blockage issues with number 4. The empirical database is very -- is limited with respect to fuel dispersal and mechanical energy generated as a result of fuel dispersal.

Technical challenges, which will need to be overcome in dispositioning this regulatory position would be that the flow channel blockage by the fragmented fuel and cladding particles would need to be quantified, and its effect on long-term cooling would need to be qualified.

The same goes with fuel rod ballooning. The fuel coolant interaction, mechanical energy from the dispersal of the fuel would need to be evaluated, and once again the pressure pulse, potential pressure pulse that's generated would need to be qualified.

And finally, the transportation of fragmented fuel particles throughout the reactor coolant system needs to be assessed with respect to the radiological source term, doses to the public and workers, plant EQ, coolability, and potentially even criticality.

CHAIRMAN ARMIJO: Now if this occurs during -- presume that these events occur while there's full reactor flow or partial reactor flow. Is that the scenario we're addressing, or is that one of just many?

MR. CLIFFORD: If you look at the TSARS for the current operating fleet, whereas every other event is analyzed for 30 minutes or longer, there's a general requirement that the, say, a turbine trip, they would run the event for 30 minutes. They would then show that the reactor trip functions and the SFAS systems were capable of mitigating the consequences of bringing the transient to either a new plateau or a decrease. In other words, temperatures were decreasing. Pressures were decreasing. The event was getting more benign with time.

This particular event is only analyzed for five or ten seconds in all of the SRs. You don't have that long-term plant response in the past where we haven't requested it. It's really -- in the past we've always focused on the first five or ten seconds.

How much fuel to you fail? Do you melt fuel? And are you going to blow your reactor vessel in the first fives seconds? We never look at anything past that.

CHAIRMAN ARMIJO: But coolable geometry, I would think, would take -- is more than a five-second problem.

MR. CLIFFORD: Right. Coolable geometry we kind of get into the situations where we are LOCA. You know, how do you evaluate, you know, what's going on over a period of time? You have a requirement to maintain a core coolability, but how do you demonstrate that if you've got particulates of fuel and cladding that's floating around in your RCS? It's a difficult question to answer.

CHAIRMAN ARMIJO: Well, I hope the Industry has some ideas on how to address these things, because this is what you intend to evaluate in the submissions.

MR. CLIFFORD: Correct.

CHAIRMAN ARMIJO: You want to see --

MR. CLIFFORD: We would like to see these --

CHAIRMAN ARMIJO: -- documents that address that.

MR. CLIFFORD: -- addressed and dispositioned somehow. I mean, they may be able to -- for instance, like a PWR rod ejection is a break in the upper head, so you may be able to disposition that by saying the long-term transient, you know, after five seconds, I going to be very similar to a LOCA, because you have a break I the reactor vessel.

It's depressurizing. You know, you have your ECCS system responding to the event as though it's a small break LOCa, so maybe one of the approaches would be to demonstrate that it is bounded by a LOCA analysis so you don't have to go into any further detail, but, you know, it depends on, you know, what's presented to us. I guess we're just identifying what needs to be dispositioned and then allow them the flexibility of dispositioning it.

CHAIRMAN ARMIJO: Okay.

MR. CLIFFORD: Okay, the last slide is implementation, and we talked about this at the very beginning. The interim criteria was developed to support the licensing of the new reactors, the next generation of reactors and will be used by the staff in their review of all the COL applications and design certification documents.

Over the next 18 months or so, we will be doing more rigorous evaluation and awaiting further data from the Japanese test program and, if necessary, revising the particulars of the acceptance criteria and guidance.

Like maybe the curves will change slightly if we get more data points, and maybe we'll adjust the fission gas inventory as a function of pellet power, and then we intend to finalize the criteria and revise the impacted Regulatory Guides and probably again revise the SRP to replace the interim criteria with final criteria.

During this period, we'll also be issuing -- I shouldn't say during this period. In the next two months, we intend to issue a RIS, which is a Regulatory Information Summary, which is a vehicle for NRR to communicate to the public and to the Industry as to how we intend to implement this, because I know there's a lot of concern.

There's a lot of confusion. Who's going to implement it? When are they going to implement it? You know, what's it going to look like? So we're going to try to address all that in a RIS. That's our plan right now and get that out on the street within about two months.

And during this period -- as I mentioned, there were two reasons why we were doing this in the beginning. The first reason was to develop justifiably conservative acceptance criteria and guidance for the next generation of reactors, and the second reason was to provide a target for the Industry to use in developing a strategy for implementing the final criteria, and we strongly encourage that the licensees and vendors develop and submit new 3D core neutronics methods and also develop a strategy for dispositioning the long-term effects on coolability.

That's what I have.

CHAIRMAN ARMIJO: Okay. Any questions from the Committee? Tom?

MR. MENDIOLA: If I may, that concludes the staff's presentation on this topic for today. I hope it was informative, and I guess if there's any suggestions on the material, how we could provide it for the full Committee meeting later this week, it would be helpful to understand where we could focus our presentation.

CHAIRMAN ARMIJO: How much time do we have on the agenda, Ralph, do you know, for the full Committee?

MR. CARUSO: An hour and a half total.

CHAIRMAN ARMIJO: An hour and a half, so --

MR. CLIFFORD: That would include the Industry, too?

CHAIRMAN ARMIJO: Yes, so it's going to have to be pretty condensed.

MR. MENDIOLA: I mean, any suggestions you may have or would like to provide us on where we should focus that would be ideal, but we recognize it's a very difficult topic to move quickly through but just a suggestion. We can do that.

CHAIRMAN ARMIJO: I think we should talk about that after we hear from Industry --

MR. MENDIOLA: Yes.

CHAIRMAN ARMIJO: -- and see how we

apportion the time and get some ideas what would be the most effective way to get this across in some way that it'll actually get finished. So if you don't mind, we'll just hold off.

MR. MENDIOLA: That's fine.

CHAIRMAN ARMIJO: Since we're ahead of schedule, let's keep going, and I'm assuming there's no problem with continuing.

MR. CARUSO: No.

CHAIRMAN ARMIJO: We'll just keep rolling through, and I think our next presentation would be Dr. Ozer from EPRI and Montgomery from Anatech on the interim RIA criteria.

DR. OZER: Good morning. My name is Odelli Ozer, and I'd like to, first of all, thank the Committee for giving us this opportunity to present the Industry position. Also, I'd like to thank NRR for having afforded us the opportunity to listen to our concerns and afforded us an opportunity to express them at a couple of workshops and interactions over the phone, as well.

Even though this presentation and the following presentations have either my name or Robert Montgomery's name or Gary Darden's name, I'd like to make the point that these are really presentations that were prepared jointly by the working group of the fuel reliability program, so they really represent not just our personal views but the consensus view of the working group.

EPRI has representation from all the U.S. nuclear utilities as well as a large significant number of overseas utilities, and we have all the vendors participating, all the major vendors participating in this, as well.

As far as the Industry perspective on the interim criteria that were proposed by NRR, we consider this criteria to be acceptable on an interim basis. We are very grateful that a number of our concerns have been addressed, namely the separate treatment of the coolability limit. There were concerns of the RIL0401 was proposing collapsing that onto the failure limit, and there were a number of other items, as well, that are important, and they have been addressed.

The one problem we have is that a lot of what I'm probably talking about will be based on the two documents that we saw, the draft of the SRP 4.2 that was released early in February and the technical basis document that was released in mid-January. Since then, we've had a lot of discussions, and it's possible -- we anticipate that some of these changes may occur in the final version of the SRP, but I will be mentioning them here anyway, because we don't know whether they will be there or not.

The areas that we feel our concerns have been addressed include the recognition of the prompt versus delayed pulses. This is particularly important for cold BWR where the delayed pulse can be a significant fraction of the total pulse.

So, you know, when you put a limit on the BWRs, it really -- it's the prompt part that is driving. The limit should be on the prompt part, not on the total and things that, you know, similar things with regards to clear definition of terms, but we feel that there are several key areas where improvement still is needed, but we think that that's really something that we'll be working on for the final criteria.

There are some issues, of course, about the implementation. We had some questions about that, whether these interim criteria will be implemented towards the current fleet of plants, and I think that has been addressed by Paul. We do have some, you know -- again, because this was a question that was in flux, we may be coming back to that again.

But our main areas where we would like to work involve the amount of conservatism that is included in the failure threshold. We feel that the RIL0401 still has exercised, you know, too much influence on the failure, definition of the failure threshold, and we are concerned about the extent of work that will be needed to address the coolability issue on an industry-wide basis, but we look forward towards working with NRR toward development of these improvements in time for the final criteria.

We are also a little concerned about the timing. You know, if the final criteria are targeted for 18 months from now, it really -- it's not much time. We're concerned that there won't be much more experimental evidence coming in within the next 18 months.

Our perspective on RIA. First of all, in the last ten years since it became evident that high burnup fuel may fail at a lower level than the criteria that were present, the industry has invested a considerable amount of R&D resources into this issue. We studied it thoroughly, and I feel that we obtained a very good understanding of the key phenomenon that are in action here, and we feel that the test results can be explained in terms of just pellet-cladding mechanical interaction in the burnup range that we are interested in, the time-temperature history resulting from the energy pulse and the cladding ductility.

Public expense puts pressure on the cladding strain, and the question is whether cladding will withstand or the cladding has enough ductility to withstand that. There are no magic, no unanticipated phenomena that are taking place at least, again, in the burnup range that we're interested in and within the enthalpy levels that we're interested in.

This is -- you know, we've been planning this for the last few years. Most recently this has been -- there has been a seminar, a workshop at CABRI where this was really organized, I think, at the recommendation of NRC that CABRI sits back and tries to summarize the lessons learned from all the experiments, and I have some backup slides in the handout about what the lessons learned were from this CABRI seminar. They are pretty consistent with what we have been saying all along.

To obtain this understanding, we developed a mechanistic methodology for the analysis and predictions of both the experiments and what will the response be in a reactor. It's rather straightforward.

We used a fuel photomechanical code with FALCON. It's a 2D final element methodology code, and it's very simple. We just input the power pulse that the test rod sees during the test and tried to calculate what is going to be the pellet response.

Now this is a plot of half of the pellet. This is the outside boundary, this is the cladding region, and this is the center of the pellet, and originally the temperature is low. The first thing that we noticed is that it starts to rise in the rim region here, and very quickly it rises way up while the center of the pellet follows, and eventually the rim temperatures decrease slowly while the center of the pellet feels the impact of the energy pulse, and long after the energy pulse is over we have a parabolic distribution as before.

The thing to note here is that very early on the cladding temperature is very low. It's down here, and it heats up, eventually heats up, so the question is do we have enough time to heat up the cladding to improve its ductility. Very narrow pulse, we don't have the time. You know, wider pulse, the cladding heats up and has much more ductility.

CHAIRMAN ARMIJO: Now this preferential

heating at the periphery of the pellet, is that valid for fresh fuel, as well as high burnup fuel?

DR. OZER: No, this is for high burnup fuel. You have to have a rim.

CHAIRMAN ARMIJO: Okay.

DR. OZER: You have to have a rim, and, in fact, I will be talking a little later about the differences between UO_2 fuel, which has a rim, and MOX fuel, which does not have a rim like the UO_2 fuel but has many multiple rims around each of the plutonium grains within the pellet.

Now, so we use this to -- this calculation of temperatures and pellet expansions and pellet -- stresses that the pellet will exert on the cladding to determine the cladding strains, and we compared those to the measured strains. So this is a calculated strain, and these are the measured points for EPRI tests.

So this is, you know, a basic difference between our approach and the approach that NRC has used is that we start from basic principles, try to calculate, see whether we can predict what's happening in the experiments, and then we go to try to make a prediction in a reactor, whereas -- you know, so we use the experiments, the RIA simulation experiments, primarily to validate our approach, to give us confidence that what we're doing is correct.

CHAIRMAN ARMIJO: Now just to make sure I understand, is this one validation step that you've gone through?

DR. OZER: This is just an example.

CHAIRMAN ARMIJO: Okay, but there's been more? You've done it for more rods --

DR. OZER: That's right.

CHAIRMAN ARMIJO: -- and fed that back into your model?

DR. OZER: Exactly, yes.

CHAIRMAN ARMIJO: Okay.

DR. OZER: And all of that has been documented in a report, and we use this knowledge to propose changes to the criteria. We found that we obtained very good agreement with the measurement on all non-failed cases.

We found that we -- you know, there is something funny about the failed cases, and we went and looked at them, and in every case they turned out to be some unique characteristic. Either the tests were done at room temperature, or in the case of CABRI, they were done on severely spalled, and cladding has really large hydride blisters, or they were MOX fuel.

So we proposed criteria and several of those were reviewed to NRC in a topical report in April of 2002. You know, since submitting this report, we also had several workshops to discuss the technical approach that was used, the assumptions that were used, and we provided NRC staff with training on the use of the FALCON code. In fact, we offered them the FALCON code so that they could try to duplicate or try to do an independent evaluation of our results.

The topical that we submitted was not accepted. We received a number of questions indicating staff concerns. They were primarily with how we treated the uncertainties in mechanical properties. Again, we used the mechanical properties to feed the code to calculate what happens in the test.

Well, there is less scatter in the mechanical properties, and we used the best estimate. You know, they were suggesting different approaches, you know, and we used a metric to determine when fuel fails, which we call the strain energy density, critical strain -- we use critical strain energy density.

We could have used another metric. We

could have used total, you know, plastic elongation, and, in fact, you know, that was questioned that we are using this new metric, and there were some concerns with our coolability limit approach, as well.

One thing I'd like to point out about the metric that we used is that you could use a different metric, but if you use a similar approach, you end up with pretty much similar failure occurs. This is the plot that we took out from a presentation put together by the Swedish authorities and presented various places, ANS meeting and the CABRI meeting by Jan In de Betou from the Swedish Nuclear Power Inspectorate, and, you know, what he calls present study here is really the Swedish study, which is this line here, and he compares that to the line that we proposed, which drops really below his estimate, and he also included a calculation done by Battelle-Northwest using FRAPCON and also total elongation, I believe.

Now, you know, yes, there are some differences, but you can see that these all bunch pretty much together. This is the staff research proposed failure criteria proposing RIL0401. It's way down. It's inconsistent.

MEMBER SHACK: Now on that best estimate, as I recall that data, I mean, it was truly a shotgun.

DR. OZER: Yes. It was. Well, there are large variations, and we can treat them -- what we did was to do a best estimate to that data and then tried to use a very conservative burnup-to-oxide. You know, we need to -- we tried to translate this to a burnup space, you know, so this is burnup here.

So to go from, you know, to go to burnup from, you know, the real variable, which is hydrogen, and we were using oxide as the surrogate, to go from oxide to burnup we used a very conservative oxidation curve for Zirc-4, which should have really covered it. And, yes, we --

MEMBER SHACK: Why didn't you just use a conservative one for the failure criteria instead of the best estimate? I mean, that would seem like the logical place to put the conservatism, where you have all the scatter.

DR. OZER: Yes, if we had done that and used a conservative oxide-to-burnup approach, as well, we would have predicted every surviving test to have failed, whereas, you know, our predictions of the surviving tests are pretty good. So, you know, that would have been an overly conservative approach, but, you know, what we could do is --

You know, since then, since we've received this feedback, we've been looking at different ways of addressing the uncertainty issue, and we have done a statistical approach. We tried to eliminate some of the tests that were not that relevant to RIA, let's say, focus on a burst test, for example. Just use burst tests. Try to fit those and do, you know, a statistical 95-95, whatever, approach.

We also even tried a Monte Carlo approach, and, you know, we can get different results with those. You know, some are lower, but they are still higher than the RIL0401 guidance.

MEMBER SHACK: I notice you didn't -- there's a criticism of FALCON that it under-predicts fuel temperatures. Is that something that you've agreed with in the SCR?

DR. OZER: Robbie, can you comment on that?

MR. MONTGOMERY: I can comment on that, yes. Robert Montgomery from Anatech. We didn't list it on the slide. We've provided the staff with our input on that. We don't believe it underestimates the fuel temperatures.

DR. OZER: Now, you know, so this was a comparison with RIL0401. As far as the interim criteria is concerned, we did participate in their development. We provided oral comments at NRR workshops and responded to, you know, provided technical input for the written and oral and provided written documents on the draft criteria.

Some of these have been incorporated into the technical justification document, in particular the improved definition of non-PCMI failure criteria, the recognition of the prompt versus delayed pulse effect, the consideration of the role of hydrogen, particularly for BWRs, and we've identified areas for further improvement.

Now as far as a summary of the remaining that we have, they have to do with implementation, the enhancement of the technical basis for the PCMI failure criteria, and the definition of the approach and methods needed to address the coolability issue.

Now as far as the implementation of the current plans, you know, we were very concerned about whether they would be -- the interim criteria would be implemented to the current plants, and there was a letter that was put together under NEI's auspices, and that was submitted to NRC.

Essentially, the letter says that since these are interim criteria, and final criteria are expected only within, you know, a short time that we should really be focusing -- you know, if implementation is to be considered, it should be on the final criteria and should provide sufficient time so that the appropriate methodology is developed, and we felt that early, you know, too early implementation may have a considerable impact on the core design process.

As far as our concern with the failure criteria are concerned, we feel that the failure criteria still are a subjective lower bound of adjusted RIA-simulation tests. Again, we have to adjust the RIA tests to give us an idea of what that fuel would have responded like if it was in a reactor situation.

So you're taking room temperature rods, rods that have experienced a four millisecond pulse, and tried to translate those into, you know, pressurized high temperature, or in the case of BWRs we argue that if it's at room temperature the pulse is much wider, so almost an order of magnitude wider.

MEMBER SHACK: Odelli, I'm getting confused.

DR. OZER: Sure.

MEMBER SHACK: If you go back to your slide 7, this criterion, that's the thing. Now do you agree with the comparison that they've made in the technical basis document between the interim criteria? I'm assuming that your mechanistic one here you've -- everybody's plotting against different variables, so I can't get a one-to-one comparison.

DR. OZER: Yes. Right.

MEMBER SHACK: Is their translation of your criterion onto their plot, do you think they've done it correctly?

DR. OZER: In what Paul has presented or --

MEMBER SHACK: What Paul presented.

DR. OZER: Yes.

MEMBER SHACK: That's really the -- we're still talking about the same curve, or is that a different curve?

DR. OZER: Go ahead.

MR. MONTGOMERY: The curve that Paul plotted is a different curve than the one that was submitted in 2002. That's in the -- that Odelli's talking about and showing here on this curve.

MEMBER SHACK: Okay, so that's a different curve still, so there's three curves floating around.

MR. MONTGOMERY: Yes, and that one has not been finalized or submitted to the NRC for any review or anything at this point. This is just --

MEMBER SHACK: How would this curve look

compared with this curve if I plotted them against the same variables?

MR. MONTGOMERY: Dr. Shack, you'll have to be a little more specific which is this curve and which is that curve.

MEMBER SHACK: Paul's curve with -- he's got fuel enthalpy rise and oxide wall thickness versus this curve where I have radial average fuel enthalpy and burnup.

MR. MONTGOMERY: Okay.

MEMBER SHACK: And I can't compare the curves at all, because I've got different variables.

MR. CLIFFORD: If you look at my slide 14, the green dotted line was what we call a 95 percent lower bound. That's something they provided --

MEMBER SHACK: Since.

MR. CLIFFORD: -- since, but if you were to take that point at 150 calories per gram and just draw it out all the way to about .16 and then start lowering it slowly, that would be more in line with what the original entry was, yes.

MEMBER SHACK: The original plot. Okay. Okay.

MR. CLIFFORD: You agree with that?

MR. MONTGOMERY: I would agree with that.

MR. CLIFFORD: And, you know, that curve, again --

MR. MONTGOMERY: About .12 when it would start to drop down. Is that what you said?

MR. CLIFFORD: I said .16.

MEMBER SHACK: He said .16, but close enough.

MR. MONTGOMERY: I think closer to .12, but, you know.

MEMBER SHACK: At least it gets us somewhere in the same universe.

MR. MONTGOMERY: It should be noted, just to finalize this or at least clarify this, it should be noted that in the original proposal that's shown on the figure here in terms of burnup, we did not consider the effects of spallation. Spalled rods were not considered in the development of that curve.

In the development process that we looked at in the curve shown in Paul's slide, slide number 14 that says "EPRI mechanistic 95% lower bound," that curve was developed considering the effect of spallation, so there is a different-end approach that we are currently exploring to consider the effects of spallation and at least identify how they would impact a statistical assessment, and then we can decide later on which approach we want to take, considering spallation or not, so in the figure that's shown or the curve that's shown on slide 14 in Paul's presentation includes the effect of spallation, which the previous study did not.

MR. CLIFFORD: Another important point is you had mentioned earlier that why did they use a best estimate fit and then put the conservatism in the burnup talks like conversion. The slide here on 14, the line here is a 95 percent lower bound, so it's not the earlier best estimate fit.

MEMBER SHACK: Yes, but did you get the 95 percent from the Monte Carlo on all the uncertainties, or is this just a 95 percent on the CSD?

MR. CLIFFORD: 95 percent of a Monte Carlo of all the uncertainties.

MEMBER SHACK: All the uncertainties.

MR. CLIFFORD: That's correct.

MEMBER SHACK: Okay, which seems like the way to do it.

MR. MONTGOMERY: Yes. Now you get into the discussion of the data that you use and what you consider in terms of spallation and that sort of thing.

DR. OZER: Yes, that curve was -- again,

we've been working, trying to address the uncertainties in different ways, and we did not identify it in a formal topical report. That's --

MEMBER SHACK: That's not an official EPRI curve.

DR. OZER: The concerns that we have with the current, the proposed failure criterion for the interim criteria is the use -- the adjustments that were made to the data contain some really questionable assumptions, and we question the applicability of FRAPTRAN to this kind of RIA situation where it hasn't really been very well validated, we feel.

As far as the assumptions, in order to match the observed results, they have to assume that the cladding gap for these high-burnup rods was of the same magnitude as fabricated, fresh-cut. Otherwise, you know, they could not predict the observed, you know, strains.

And the assumptions that were made, that there is no difference between UO_2 and MOX response, that room temperature and hot-zero power cladding ductility is pretty much the same -- it doesn't change that much -- and that high corrosion cladding with spalled and unspalled cases responded the same way, and this results in a failure criterion that that is, you know, lower than it needs to be for moderate oxide thicknesses due to these biases.

CHAIRMAN ARMIJO: As far as that gap issue, if all of these rods were prefabricated before the test, you know, how does anybody know what the gap is? I mean, there's a lot of machining and drying out, rewelding, refilling the gaps. How does anybody know what the gaps are?

DR. OZER: In the RIA tests they are conditioned. They run for a while, and, I mean, the cladding is the same cladding, and they're just putting encaps, so, you know, if the cladding has collapsed, they will not pressurize it to the point that it will, you know, expand again, so it will have the gap that it has at the end of life, but, you know, you may question whether they --

CHAIRMAN ARMIJO: Well, whether it's fragmented fuel, whether it's relocated during the cutting and the machining and welding end plugs, a lot of things happen. I'm just wondering how.

DR. OZER: Well, all of those things will tend to make the gap even smaller.

CHAIRMAN ARMIJO: Yes.

DR. OZER: So, you know, assuming that you have initial gaps is really going the wrong direction.

CHAIRMAN ARMIJO: Okay.

MR. MONTGOMERY: Dr. Armijo, I should also point out that these are primarily high burnup rods, so the residual gap is quite small to start with, so even if there is some uncertainty, if it's five microns versus ten microns, it's not going to be a huge effect on the performance of the rod either in the predictions or the test itself.

CHAIRMAN ARMIJO: So how does that compare with the as-fabricated gap that was the adjustment made by --

MR. MONTGOMERY: The as-fabricated gap would be on the order of about 100 microns, 90 to 95 microns, so we're talking about a residual gap on the order of five percent or less typically for these high burnup rods.

CHAIRMAN ARMIJO: Okay.

DR. OZER: I would like to address all of these points one by one. First of all, as far as MOX versus UO_2, it's very obvious that, you know, MOX doesn't have a rim in the same sense as UO_2. Instead it has multiple rims around each of the grain, each of the plutonium oxide grains, and that results in more of the pellet responding to the challenge, and, in fact, to produce the same amount of stress on the cladding that a MOX rod that is hit with 80 calories per gram energy input, if you want to produce the same amount of strain with a UO_2 pellet, you would have to hit that UO_2 pellet with probably twice that amount of enthalpy.

So, you know, they are pretty different, you know, different types of fuel, and in countries where MOX fuel is utilized extensively, they either have implemented separate MOX criteria or are proposing to use separate MOX criteria.

CHAIRMAN ARMIJO: And would those be more conservative than the UO_2?

DR. OZER: Oh, yes. The MOX criteria would be lower than UO_2.

CHAIRMAN ARMIJO: And specifically what's that? Is that French or what? What country is it?

DR. OZER: The Swiss have, I believe, implemented already. The French are proposing. The Japanese, I don't know. Rob?

MR. MONTGOMERY: I can't speak to the Japanese.

CHAIRMAN ARMIJO: Okay.

DR. OZER: There is also -- in RIL0401 there is the argument that there isn't really that much improvement in the elasticity of the cladding as you go from room temperature to high temperature to operating temperatures. This is a bunch of NFIR burst tests. These are at room temperature. These are at operating temperature, 300, 350. There is a factor of almost three improvement in total plastic elongation.

There is the claim that hydride blisters, you know, don't play a role, and yet all the failures that we see originate at hydride blisters. You have brittle failure which then propagates by a tear. In cases where you have non-spalled situation, you go to an eight percent extension, and you finally fail here, whereas when you have spalled oxide, one and a half percent is sufficient because of the initiation of the crack within the blister. Again, it's hard to see, but this is the blister here, and here is a blister.

MEMBER SHACK: Well, the SCR says that the cladding cracks were not associated with hydride blisters or spalled locations.

DR. OZER: We disagree with the SCR.

CHAIRMAN ARMIJO: Well that's a -- you have a factual disagreement.

DR. OZER: Well, I don't think that we are the only ones to disagree with this. In fact, one of the things that comes up from the CABRI symposium -- do you know what slide it is, what's the number of the

--

MR. MONTGOMERY: 23 and 24.

DR. OZER: Here, these are the main conclusions of the CABRI seminar based on the tests, the CABRI tests. Hydride content distribution and orientation is the main parameter leading to the decrease in cladding ductility.

Non-spalled UO_2 rods have sufficient ductility at 80 to 100 microns of oxide thickness to survive up to 100 calories per gram. I mean, this is the CABRI program participants' conclusion.

CHAIRMAN ARMIJO: That is a working group.

DR. OZER: It consists of the representatives from regulatory agencies from all over Europe and Japan. NRC participates in that, the French, of course.

CHAIRMAN ARMIJO: So the question is whether you have spalled rods in the power plants.

DR. OZER: Whether you -- it's not only -- spallation by itself is not sufficient. You have to operate in a spalled mode for long enough to form a hydride blister. It's the blister, the hydride blister, that is reducing the ductility of the cladding. Incipient spallation, it is questionable, you know, what the effect will be.

CHAIRMAN ARMIJO: Okay.

MEMBER SHACK: Just let me ask the staff if they have any comment on that. I mean, your statement is that the spalling did not cause early failure but simply was a consequence of heavy oxidation that performed, produced uniform hydrides, which degraded ductility. So everybody agrees that having lots of hydrogen and hydrides is bad. The question is whether the blisters and the spallation itself played an actual role.

MR. CLIFFORD: I'll defer this to Harold. That position was developed by Research.

MR. SCOTT: This is Harold Scott from the Office of Research. I guess we weren't prepared today to rebut all of the industry items, but I don't think you should assume that because we're not that we agree with what they're saying.

As an example, in the CABRI tests there were many cracks found in the PIE metallography that were not associated with the blister. They just didn't happen to be the one that cracked through first. We don't know if it --

CHAIRMAN ARMIJO: No, but the primary crack is what's of interest, the one that actually caused the failure. There can be subsequent cracks that are not particularly interesting. You know, it's the one that actually causes the thing to fail. If the primary started at blisters, you know, we'd certainly like to know that.

MR. SCOTT: I don't remember exactly, but it seemed like in one of the tests there were several cracks that actually went through the wall.

CHAIRMAN ARMIJO: It kind of makes --

MEMBER SHACK: There still is a debate going on.

MR. SCOTT: There's a debate going on.

CHAIRMAN ARMIJO: But it kind of makes sense that there's a lot more hydrogen in a blister than there is in just a uniformly distributed rim, and if hydriding is the mechanism, it's reasonable to expect that the highest concentration of hydrides is where you would have your minimum ductility.

MR. SCOTT: That would be true.

CHAIRMAN ARMIJO: So this kind of hangs together, this argument that the blister is certainly representative of spalled rods, and I certainly know that spalled rods can exist in power reactors. Maybe that's old fuel versus new fuel. I don't know, but I wish -- I'd sure like to see the staff address that so that we just aren't arguing that cracks don't form in blisters or the cracks do form.

MR. SCOTT: Didn't.

MEMBER SHACK: You're testing the --

CHAIRMAN ARMIJO: Yes. This is an issue of fact rather than judgment, and so I'd sure like to get that cleared up so that we --

MR. SCOTT: The tests in the Japanese in SRR were not spalling. They have cracking failure. So go back to Odelli's slide of the strain, the uniform elongation versus, yes, total elongation.

If we plot other data, it may not show that strong a trend. It also, in the analysis that we did, we found that making the assumption we did gave a closer representation of the data and the analysis, and this one would seem to give a -- spread the data points apart after you adjusted them by using a stronger temperature versus elongation.

CHAIRMAN ARMIJO: Okay, so we can conclude there's a disagreement.

MR. SCOTT: Yes.

MEMBER SHACK: That much is clear.

CHAIRMAN ARMIJO: It's clear. Okay.

DR. OZER: To address the question of how much spallation we would have to assume can exist in current fleet of reactors, I'd like to note that none of the advanced cladding have shown any indication of having spalled. M5 cladding, you know, just doesn't oxidize that much, and ZIRLO cladding, even at high oxide thicknesses, the rod that was pushed to really high oxide thicknesses in the vendor's reactor by irradiating an extra cycle under rather high-duty conditions did not spall.

So in keeping that in mind, you know, that the cladding that's most susceptible to spalling is Zirc-4, this is the current inventory in U.S. PWRs. The red line here is ZIRLO, and it's almost, you know, 67 percent. M5 is 12.5 percent, so, you know, this is 80 percent of the total fleet is advanced cladding.

The only plants -- there's only 20 percent of the inventory is Zirc-4, and this really tends to be in plants that don't have a high-duty expectation, so the probability of spallation is very small, and this is really the trend is for these to go down and these to go up, looking at just, you know, last year versus this year and projected.

So, you know, we need to keep that in mind when assigning weight to the spalled rods in determining the --

MEMBER SHACK: But again, the proposed criteria wouldn't penalize the ZIRLO, because it's not going to have a thick enough oxide to put you out on that --

DR. OZER: You would have to develop -- yes, you would have to develop special criteria for ZIRLO or justify ZIRLO can use a different set of criteria. I think, you know, Paul showed a line that --

MEMBER SHACK: Wouldn't his -- his criteria with the oxide thickness, doesn't that kind of cover ZIRLO, because it's going to have a thin enough oxide that you're going to be down in that, the high energy?

DR. OZER: It will not cover ZIRLO. It may cover M5.

MEMBER SHACK: M5 but not ZIRLO. Okay.

DR. OZER: But not ZIRLO, and ZIRLO should not be penalized for spalling.

CHAIRMAN ARMIJO: You're saying ZIRLO shouldn't be penalized for spalling if it's not actually happening there.

DR. OZER: Yes. We have not seen any.

MEMBER SHACK: So ZIRLO is going to be somewhere in this .12 range that you're concerned about.

DR. OZER: Yes.

MR. MONTGOMERY: Actually, it's more like

.8. Once you get to .08, you've kind of reached your -- that's like 50 microns or so.

CHAIRMAN ARMIJO: As long as we're at it, for the BWRs, Zirc-2, do you have something similar for that? Is the improved Zircoloid 2 more resistant to spalling than the older versions?

DR. OZER: I'm sorry, I don't have that information.

CHAIRMAN ARMIJO: Okay.

DR. OZER: The areas where we would like to see the BWR criteria improved is -- you know, Paul showed you a curve that we fixed to NSRR data, and those NSRR data were obtained with four-millisecond pulses versus a 30-millisecond pulse that we would expect in an actual BWR, so, you know, we're adjusting the PWR data upwards to account for these differences. We feel that the BWR data should be adjusted, as well. So, you know, we just feel that those are conservative. What has been proposed is conservative.

There is some concern about the application of the interim criterion to hot-zero power cases. We feel that when you allow the BWR cladding to heat up, the criteria that we propose for PWRs should be applicable at high temperatures, so, you know, you should be able to switch.

CHAIRMAN ARMIJO: You're saying the cladding mechanical properties should be adjusted.

DR. OZER: Well, the criteria should be. We should be allowed to use the PWR criteria for BWRs at hot power.

MR. MONTGOMERY: Because of the improvement in the mechanical properties of the BWR cladding, it should go from room temperature to hot conditions. It's because of the mechanical properties.

DR. OZER: And there is some concern about the language that is being used, because, you know, we're using the most conservative -- we're using the lower amount of the experimental data, and that has to be combined with the most limited accident analysis, so it seems like we're piling up uncertainties all in the same direction.

This is some data to show the improvement in the BWR cladding mechanical behavior with temperature. What we have here is EDC test, elongation due to contraction tests, expansion due to contraction tests. These are tests where irradiated cladding segments or pre-hydrided cladding segments are filled with a plastic core, and then the plastic core is pushed to expand to simulate an RIA experiment.

And what we have, what we see here is that when you have zero hydrogen, you have quite a bit more ductility than at room temperature, and then as you heat up, it quickly goes up. These points are failure points, so obviously the line has to be low all the failure points. This is a surviving point.

Now if we have some -- if we have a significant amount of hydrogen, like 250 to 350 ppm, the initial ductility is lower already at room temperature, and it takes longer for it to improve, but eventually it does improve.

It improves at 150 degrees. If you have 300 to 500 ppm hydrogen, it takes still longer, but still there is an improvement. Now we're not talking about such high hydrogen concentrations.

So we feel that there are some potential areas for improvement in the final failure criteria. Both the newer experimental data will help, as well as a fully qualified analytical approach to -- you know, if we are going to use adjusted data, let's use qualified, knowledgeable approach, and account for the most severe loading from MOX, account for the improved cladding ductility as temperature goes up, and the improved cladding mechanical response if we don't have spallation.

And my next plot shows what I mean. This is pretty much the data that -- the PWR data that has the adjustments of adjusted RIA simulation tests. These are the SRR tests. These are the CABRI tests, and this is the CABRI MOX test, and the failure criterion that has been proposed fits this, you know, has been proposed to fit this data.

What we believe is that the adjustments are not enough. These are just a temperature adjustment. These points would move up here if they were adjusted using -- you know, if this were to move up here, this one would move up here.

CHAIRMAN ARMIJO: That's just a temperature correction?

DR. OZER: Just a temperature difference.

CHAIRMAN ARMIJO: Okay.

DR. OZER: Now MOX. We go from here up to here if we account for, again, the stress that would be exerted by the UO_2 pellet on the cladding. So we would propose to raise the failure criterion, particularly in this range here, which is really the most important range for operating the reactors, and, you know, this would be taking into consideration the spalled rods, and if we don't take into consideration the spalled rods, we would have a curve like this.

It's really a shame that most of the future experiments are focusing in this range of oxide thicknesses, and, you know, these are beyond the currently licensed oxide thicknesses, and we don't expect to get there. We should be looking more in this range, and we should be looking more at the differences between MOX and UO_2,but, you know, we hope that, again, using a better, more systematic approach we can justify using this kind of a curve.

CHAIRMAN ARMIJO: Is there any chance of convincing the funding agencies or sponsors of these future tests to focus in the area of interest to operating plants? I don't know who makes those decisions, but that's where you'd put your money.

DR. OZER: Well, it's, you know, we may have a chance with the CABRI experiments, especially if we can get NRC's support. You know, we are both participating in that, but again, it's we would have to convince the other sponsors of the CABRI program that this is a good approach, that this is where the data is most needed.

We have less control over the NSRR experiments, because they are sponsored by the Japanese government, but again, we can try to convince them. That's the only thing we can do.

MR. SCOTT: Excuse me. This is Harold Scott. Could I just comment on -- since you moved that MOX point so far, but you had a slide before that said that the strain is primarily a function of the thermal expansion. Well, the thermal expansion of MOX is not twice UO_2, so I don't know why that point moves so far.

DR. OZER: To produce the same amount of strain on the cladding that a MOX rod would produce under 80 calories per gram, you would have to insert 150 or 140 calories per gram into a UO_2 pellet. It's --

MR. SCOTT: Is it the neutronics? Is the neutronics there not --

DR. OZER: It's not twice the expansion. It's where, you know, where the expansion is happening, you know, the rim being on the outside in the UO_2 versus, you know, the entire pellet contributing in the case of MOX.

MR. SCOTT: Well, that's one answer, I guess. Okay.

MR. MONTGOMERY: Harold, let me see if I can try to answer that question for you. The conclusions from the CABRI seminar were only focused on UO_2, so the conclusion that -- UO_2 pellets, so the conclusion that the primary driving force for clad loading is from thermal, pellet thermal expansion, only applied to UO_2, not MOX.

In MOX you have an additional component. That could be the contribution of fission gas expansion in the plutonium conglomerates that could be expanding the pellet additionally above the thermal expansion.

CHAIRMAN ARMIJO: So there's more than one mechanism in play in MOX fuel.

MR. MONTGOMERY: That is the current expectation, yes.

MEMBER SHACK: Yes, but that seems to be counter to this one, that it takes so much more energy to get another mechanism to drive it up.

MR. MONTGOMERY: What we're saying there is that that rod failed at somewhere 100 calories per gram as a MOX rod, but the cladding strain that it saw was about -- which would be the expected amount to cause it to fail. To get the same amount of cladding strain in the UO_2 rod, you'd have to increase it to a higher level. So that's the -- the hash symbols there are the translated data point into a UO_2 space.

CHAIRMAN ARMIJO: Okay.

DR. OZER: As far as the coolability limit is concerned, we see that there's a fair amount of effort that will be required to disposition of it. There are two concerns.

One is the short-term, the impact of hot particles being released into the coolant and the pressure pulse that may result from that, and ten there is the longer term concern that Paul talked about that the redistribution of the disbursed material and the coolability questions, the ballooning and so on.

I think what we would like to do in this area is really try to see whether they can be -- to what extent they can be addressed on a generic basis, maybe provide a reference so that individual licensees can decide whether they want to use that or whether they need additional relief to do some additional calculations of their own.

CHAIRMAN ARMIJO: Topical reports that other people could reference --

DR. OZER: Yes.

CHAIRMAN ARMIJO: -- and justify applies to their plants.

DR. OZER: Yes.

CHAIRMAN ARMIJO: Okay.

DR. OZER: So as far as the "final"

criteria is concerned, we look forward towards working with NRC to reach consensus on these. We hope to enhance the technical basis of the failure criteria using the newer data and improved analytical methods and develop approach to disposition the coolability concerns.

CHAIRMAN ARMIJO: So you don't really -- your next-to-last slide, you're saying as far as the things that needs to be addressed, you're not objecting to that. It's just how to do it efficiently --

DR. OZER: Yes.

CHAIRMAN ARMIJO: -- is your issue.

DR. OZER: I think they need to be addressed. They need to be looked at.

CHAIRMAN ARMIJO: Okay. Thank you.

DR. OZER: Thank you.

CHAIRMAN ARMIJO: These are the backup slides.

DR. OZER: Yes, the backup slides are the conclusions from the CABRI seminar, and, you know, --

CHAIRMAN ARMIJO: It might not hurt to just -- we've got a little bit of time -- just to --

DR. OZER: Well, I talked about the first one, which is that the hydride distribution orientation is the main factor and that non-spalled rods can survive to 100 calories per gram, so we expect the non-spalled limit to be about at that range.

They concur that PCMI loading is primarily pellet thermal expansion up to 110 calories per gram and 75 gigawatt-days per to burnup, and that's the range that we're interested. You know, beyond that, you know, other things may happen, but --

The others are not that relevant, I think, to -- yes, there is significant range in fission gas release from the green-grounded gases. We know that. They observed that there is up to 30 percent helium release it the total fission gas release, and they don't know why that is observed.

One thing that's kind of interesting and has to be kept in mind is they observed that during the transient, most of the CABRI tests lost their oxide layer, and this did not happen in the NSRR test, so they think that this may be a sodium effect. You have the temperature differential between the cladding and the sodium, and it contributes to the spallation of the oxide during the test.

And I also would like to mention that once a rod fails in CABRI, it should be inspected very soon, because sodium gets in there. It expands the cracks, adds additional cracks, and, you know, if you look at it three months later, you know, you don't -- you know, it's very difficult to determine where the initial crack has occurred, and I think that's what may be confusing research.

The rod that Harold was referring to was looked at, I believe, twice, once shortly after the failure and once, you know, much later on, and the cracks were much larger, had propagated, so that's one thing that has to be considered. And the last point is that the fast pulse is ten milliseconds, are more adiabatic, and lead to higher PCMI loading, less clad heating -- that stands to reason -- and larger zone of pellet fragmentation.

These are some slides to map out the MOX versus UO_2 response. This is the -- during the test, the amount of sodium that is ejected at a certain point, take a snapshot, and the lower curve is full of UO_2, and the upper curve is for MOX, the sodium that is ejected from the test rig when the fuel enthalpy reaches 70 calories per gram.

We have to cut it at a certain point, because after that point, some of the ejection of the sodium may be due to the expansion of sodium due to heat-up, so, you know, you have to catch it early on, and we already see this big difference here.

CHAIRMAN ARMIJO: So this is thermal expansion of the test rod itself?

DR. OZER: That's right.

CHAIRMAN ARMIJO: So it's the volume change of the fuel rod.

DR. OZER: Pushing out the sodium out of the rim.

CHAIRMAN ARMIJO: Okay, and you get more with the MOX than with UO_2.

DR. OZER: Okay, this is just, I think, too complicated.

CHAIRMAN ARMIJO: Yes, let's not --

MEMBER SHACK: Well, it's just nice to see such universal agreement on a criterial.

CHAIRMAN ARMIJO: It just makes our job easy

DR. OZER: Well, it's more of a historic interest, I think.

I think the next presentation -- see, we focused this presentation on just the Appendix B of SRP 4.2, but there are some additional issues, feedback that we would like to provide with the -- to NRC concerning the current version that was released, so that will be addressed by Rob.

CHAIRMAN ARMIJO: Okay. Well, we've got 25, 20 minutes before lunch. Do you think you can get your presentation?

MR. MONTGOMERY: I think so.

CHAIRMAN ARMIJO: Well, why don't we do Robs, and then --

MR. MONTGOMERY: I have 13 slides.

CHAIRMAN ARMIJO: Well, we can run a little over.

MR. MONTGOMERY: Yes, if we go to 12:15 --

CHAIRMAN ARMIJO: Yes, let's just do it.

MR. MONTGOMERY: It's only our lunch.

CHAIRMAN ARMIJO: It's our lunch. That's right. We could afford to skip a meal once in a while.

MEMBER SHACK: I have my Nutella right in my bag.

CHAIRMAN ARMIJO: Do you have the slides?

MR. MONTGOMERY: Yes, they're out here. Yes, they're in our C drive.

Okay, what I'd like to present today is a summary of the industry's comments following our review of the Standard Review Plan, Section 4.2, Revision 3 revisions that were sent out in the March, mid-March time frame.

This slide here just summarizes the outline of my presentation. I'll briefly give you some background on our views on what we've been doing in this area. This is not an area -- this is an area that we've actually been looking at primarily in terms of high burnup effects on SRP 4.2, so we have already done some of these reviews and identified some of the changes that have been developed by the staff.

Then I'd like to go through some of the concerns that we have on the revisions. I've kind of grouped them in terms of general comments and then go through the fuel system damage items, the fuel rod failure items, and then fuel coolability items, then analytical predictions, and then just a brief summary of the some of the Appendix B criteria for RIA that we've developed and actually communicated back to the staff, and then just a brief summary.

So the objective of our review was to try to determine the impact the revisions would have on the fuel and core design processes and the methods. We had previously gone through a review of SRP 4.2, Reg 3 that was issued in 1996 and developed a set of recommended changes for burnup extension applications, primarily going beyond 62,000 gigawatt days, our lead rod average burnup.

These were summarized in a topical report. The EPRI number is there. That has been provided to the staff in the last, I think, last year sometime, and they identified a number of the same items or issues that -- our review identified several of the same items and issues that were changed by the staff changes, so our recommendations are pretty consistent.

However, there are some comments, additional ones that we'd like to make. Just for applicability to future cores, we'd like all the references to zircaloy to be changed to zirconium alloy and allow us to cover M5, Zirlow, instead of talking about zircaloy.

In addition, one of the key questions here is we need some specification on how the new criteria are going to apply to current operating plants, not just in Appendix B, which we also talked about today, but also the rest of the criteria that are -- guidance is provided in the document.

Now what I'll do is I haven't gone through the whole -- I won't be going through the whole SRP. I'm just going to highlight where we identified comments, so I'll identify the section, subsection, and then paragraph where there are comments. That's what this indication is here, section, subsection, sub-subsection, and paragraph, I believe, of where our comments are.

In terms of the fuel system damage parameter related to oxidation, hydriding, and buildup of corrosion products, there are two primary comments we have. First is there's a definition there about acceptable, should demonstrate acceptable strength and ductility.

We expect that there needs to be some better definition of what acceptable means. Would that refer back to the strength and strain parameters and other sections of the SRP, or is there something, some other parameter there that's expected?

Secondly on that one, there is a focus on primarily mechanical properties defining strength and ductility, which seems to preclude the allowance of alternative approaches to satisfying these criteria. For example, thermal performance, the corrosion thickness may need to be limited based on a thermal performance and not a mechanical performance, or design tolerances may require crud, limits on crud and oxidation that don't have anything to do with mechanical performance. It could be that there's a fit difference.

Now we're not talking just fuel rods here. We're talking all the assembly components, including guide tubes, grid spacers, nozzles, and things like that. So when we're talking about defining limits on oxidation, hydriding, and buildup of corrosion products, for those other components, these other parameters may need -- other performance parameters -- other thermal performance or design tolerances could -- may define what the oxidation limits should be, so some clarification there would be helpful.

In terms of the rod internal pressure, this one, this particular paragraph has to do with rod internal pressure. There is a specification for no reorientation of hydrides in the radial direction in the cladding, but there's no definition of what no reorientation means.

For example, recrystalizing material because of the crystalline nature of the cladding material, the grain orientation, there is a tendency to have radial hydrides form, even without a tensile stress. So when you do a hot cell examination and we look at a high burnup BWR rod, for example, we could see some radial hydrides there.

Is that due to over pressurization? No, it's not, but those aren't reoriented due to system over-pressure. They were just there because of the natural tendency of the material to form some radial hydride. So how do we demonstrate compliance of this guidance is going to be a little tricky, and we need some clarification there.

In terms of the rod failure criteria or the fuel rod failure criteria, on the hydriding where it talks about both external and internal sources, the primary focus of that section has been on internal sources of hydriding related to sources coming from the fuel or other components inside the cladding.

It doesn't really seem to be appropriate to include external hydriding sources at this point in the SRP, because it really just is kind of some introductory comments, but there's no guidance given. Most of the guidance appears to be given in the section II.B.vi, which is the sources of external -- pellet-clad interaction.

That's where the external hydriding comment or issues are addressed, and we feel that just kind of some reorganization there and moving, just sticking to internal hydriding in II.1.B.i would be appropriate and then moving all the external hydriding issues to the II.B.vi would be more appropriate.

We're going to now the pellet-clad

interaction section. First there's a -- just I think this is probably more a typographical error than anything, because Dr. Wu had it in his slide that it's strain-driven, but in the document it says stress-driven, so there just needs to be a, you know, this needs to be corrected.

And then for -- there is a focus there in that section on waterside corrosion as a surrogate for hydrogen. It should be recognized that that may not apply for BWRs, so the wording there may be -- it may be more appropriate, instead of just referring to waterside corrosion, adding hydrogen content distribution and orientation as a measure of the mechanical performance may be a better definition of how to define that limit, the strain limit, instead of defining it in terms of corrosion thickness.

And also, in terms -- again, this is probably just a typographical thing. The mechanical testing should demonstrate that ductility is well above one percent strain criteria, not -- it says within. Within would apply to me. It should be below one percent. I don't quite understand that one.

Now here's one where there is some new guidance provided here in the PCI interaction, the pellet-cladding interaction section, and that has to do with power maneuvering guidance. There's discussion there about vendors have views or have provided fuel design limits based on power maneuvering.

Generally that's not considered a fuel design limit such as a ramp rate or threshold powers for power maneuvering, reactor startups or mid-power cycle maneuvers, but there is some indication there that that's now a fuel design limit, and I'm not -- it doesn't seem clear to me that that's appropriate for this particular section, anyway.

My suggestion would be to take this paragraph and redefine it and move it into a subsection unrelated to analytical predictions on PCI/PCMI. It seems like the primary focus is to define that there needs to be analytical calculations done to demonstrate that you meet the one percent criteria, and there should be some guidance on how that PCMI calculation should be done.

And that's the purpose of that paragraph, primarily, seems to me, and it should just be moved into the analytical predictions section just like the clad collapse was modified. Add a section on PCMI analysis methods. So that's what I talk about, and in that you could then remove the reference to the power maneuvering guidance.

And then we have a second point, and that is for AOO transients that are fairly short-term on the order of half an hour or less, really gaseous swelling is not really an issue, and so there is some requirement there for treating gaseous swelling. For postulated accidents, it's a separate story, but AOOs adding a requirement for gaseous swelling seems to be over specification.

Now let's move on to fuel coolability. On the cladding embrittlement there, there is a statement that says that the ECCS performance analysis must satisfy the fuel design criteria. I believe that really should be acceptance criteria in 50.46(b). I don't believe that's fuel design criteria necessarily, again, just trying to be consistent in our terminology.

For fuel rod ballooning related to AOOs, we believe that this is precluded already by other fuel design criteria. It doesn't need to be specified, and that would be in section II.1.C.iv, where it talks about AOOs, because for AOOs we're going to be limiting the cladding temperature to below the DNB limit, so you're really not going to get ballooning.

You'll be below the temperature needed to start ballooning, and you're also limiting the strain to one percent strain from section on the pellet-cladding interaction limits. So those two should preclude DNB propagation during AOOs. That's our interpretation on rod ballooning and DNB propagation related to rod ballooning. It should be precluded by the other two criteria.

Now if we just go into the analytical predictions, there was again a section on fuel temperature, stored energy calculations, which makes a reference to the clad hydriding. As far as we're concerned, clad hydrides play no role in the calculation of stored energy.

This gets back to -- it was added primarily to address PCMI-related calculations, and so we recommend a new subsection that defines the PCMI analysis methods and what the expected components would be for that kind of calculation.

And then, again, for the analytical predictions there's a reference in the mechanical-water reaction rate definition where there's two definitions of providing technical, appropriate technical data to support the model, and we believe that Reg Guide 1.157 already allows that best-estimate reaction rate model to be provided.

You know, it doesn't need to be specified twice. It's repeated a couple of times. It says you can use either Reg Guide 1.157, or you can provide your technical basis for the new model, and in Reg Guide 1.157 it says you just need to provide your technical basis for a model, so there's kind of redundancy there.

On the NMRA criteria, these are the comments that we had, and we've already communicated these to the staff, and that is, first off, it wasn't clear on what was meant by intermediate full-power operations in the SRP. In the technical guidance document that was provided that the SRP was based on, it stated greater than five percent, so we want to add rated power levels greater than five percent is what was meant by intermediate and full power conditions.

In the fuel cladding failure criteria related to PCMI, there were two clarifications that we wanted to make sure got included, and that is that first that they -- we were talking about the prompt radial average fuel enthalpy when it talks about radial average fuel enthalpy change. They were talking about the prompt part.

And then also for the hydrogen content for

BWRs, for hydrogen content to be above the solubility limit when defining the criteria, and that recognizes that -- it gives some recognition to the temperature effects on cladding ductility and provides us an option for hot-zero power BWR events to allow some improvement.

It's not all the improvement. As Odelli said, we believe there's additional improvement related to temperature, but this at least gives us some improvement in terms of the solubility limit increasing.

And then finally, this one has not yet been really communicated to the staff -- those three were -- is the clarification on the requirement of no fuel melting only applies to hot-zero power control rod ejection or control rod drop accident events that have the temperature peaking in the periphery region where you have quick access to the coolant and that fuel melting is still allowed for hot-full-power events where the peak temperature occurs at the centerline. We'd like to have that clarification.

This is already accepted. In terms of the fuel melting, we already have for hot-full-power events an accepted methodology that allows fuel melting in the centerline of the pellet.

CHAIRMAN ARMIJO: So this is a -- this is a new comment that the staff hasn't received yet?

MR. MONTGOMERY: That's correct, and it relates to the relationship to RIA. In the previous comments before the RIA, we have not communicated those to the staff yet. Just on the Appendix B have we talked to the staff, but this one was not included at that time on the centerline melt.

So our review says that there will be some impact on the fuel rod and design process, core design process of these new revisions. The impact has not been fully assessed yet. We had some concerns that we've identified, and we are going to submit those in a letter to the staff. We have not done that at this point. We will write all this up and submit it to the staff in a letter, and I hope that we can work with the staff to address these comments in the next revision of the SRP.

CHAIRMAN ARMIJO: Okay. Any questions or comments from Members or the staff?

MR. WU: Yes, I appreciate -- this is Shih-Liang Wu. Yes, I appreciate. I have a comment. Yes, this, yes, we admit that we're missing maybe a technical error in terms of like, for instance, one percent should be way above one percent, and then there's other editorial, I mean, error place like acceptance criterial instead of field criteria.

But I have one comment is when you mention the oxidation that we say that acceptable strength and ductility, well, we will consider your situation, try to look into that, you know, maybe better define, but the other point is I would like to point out is sometimes we start delivery -- not delivery.

I mean sort of make a kind of a little vague, because that's why this different brand of licensing can refer to different technology, and that's, for example, in raw pressure, system pressure, different vendor got different number. I just want to try to explain that.

Sometimes we don't deliver it. We don't specify. We just put a certain criteria and that the, you know, the industry deliver their own basis here. That's my comment.

MR. MONTGOMERY: Thank you.

MR. CLIFFORD: With respect to the notion that you don't have to consider balloon or burst or anything in AOO because you don't go into DNB, you always have to consider the critical pressure from a perspective of a depressurization event.

If you had an excess load event or a steam geo tube rupture or anything which would drop RCS pressure down towards your trip set points, you would need to ensure that you wouldn't balloon or burst during those events. That's why those words were put in there, recognizing that those events are not in DNB, but there's still the fact that the delta P across the cladding is increasing as RCS pressure is decreasing.

MR. MONTGOMERY: But ballooning and DNB propagation consequencing from ballooning would have to occur at cladding temperatures beyond DNB, 800 C-type temperatures.

MR. CLIFFORD: Right. Right. There's two mechanisms at play here. One's the rod internal pressure. The other one is the creep properties of the high -- the high temperature creep properties of the material, and I'm saying if you were to determine that no-clad liftoff during normal operation allowed you to be at -- make up a number -- 3,400 pounds per square inch --

MR. MONTGOMERY: Right.

MR. CLIFFORD: -- then you would have to show that during an AOO that you wouldn't fail that cladding because of RCSD pressurization. Now instead of 3,400 minus 2,250, it's 3,400 minus 1,800. The delta-P across the cladding is increasing during the event. You'd have to ensure that your clad maintains enough strength. Even though the temperature of the cladding is at normal operating temperatures, you have to make sure it maintains enough strength so it wouldn't balloon or burst.

MR. MONTGOMERY: Okay. I see the clarification. I think that you still would be limited by -- I can see how you can disposition that by showing that you won't balloon or burst at those temperatures.

MR. CLIFFORD: Right. I didn't -- you know, I'm sure you can disposition, but it's something that just has to be looked into.

MR. MONTGOMERY: Right.

CHAIRMAN ARMIJO: All right. Well, if there's no other comments from the staff, we're ahead of schedule, which is good news. It's noon now, and let's reconvene at 1:15.

(Whereupon, the foregoing matter went off the record at 12:00 p.m. and resumed at 1:16 p.m.)

CHAIRMAN ARMIJO: Okay, gentlemen. We're going to resume, and there have been a couple of changes to the proposed schedule. The presentation related to LOCA is not going to be given. We've completed the comments, industry comments on other SRP 4.2 changes, so we really, as far as I know, have only one presentation left, and I don't know who the speaker is going to be. Sorry.

MR. DARDEN: Okay. This is correct on here. I'm Gary Darden from Dominion Generation, so I'll be presenting this last presentation.

CHAIRMAN ARMIJO: Okay, Mr. Darden.

MR. DARDEN: All right. Thank you. I'd like to thank the Subcommittee again for the opportunity for myself and the rest of industry to present at this gathering. This presentation involves a discussion of some of the potential impact of implementing the interim criteria and ultimately the final criteria, you know, for operating plants in particular.

The Industry and staff do concur, I think. It's clear that there is not a safety issue with regard to the criteria. That's stated in our staff position, and the Industry does agree with that. As was mentioned in one earlier slide, NEI did submit a letter in early March to NRC staff for consideration to determine a potential implementing schedule for the RIA criteria, and that had two points which were mentioned earlier, that the interim RIA criteria were not proposed to be applied to existing plants, and the final criteria when those are issued have an implementation time frame of five years from release for the operating plants.

Now based on what we have heard in the presentations this morning, we believe the NRC staff position is consistent with that, but it would be good to have that guidance more specific in terms of if that is the intent of not applying the criteria, interim criteria, at all for the new plants and then -- excuse me -- for the operating plants, and it would be very helpful to have a specified time frame in which the operating plants would be needing to implement these criteria.

A major portion of this time frame that would be required is to just allow methodologies and assessments to be put in place that would support compliance with the new criteria. I've listed four key steps here that would be involved in such an activity.

The vendors and licensees would have to develop and license the criteria, the development and validating of the criteria, which could take a couple of years. The NRC first would typically conduct a generic review of the methodology, and then plants on a plant-specific basis would need to incorporate those analyses for their plant and submit that in all likelihood to NRC staff for review and approval.

So there would be a separate plant-by-plant review activity that could be involved, and all of this, you know, could very well take the five years or potentially longer that I was suggesting.

CHAIRMAN ARMIJO: Now if these criteria are applied to new plants, somebody is going to have to do exactly all of those things to meet, to have the new plants licensed, and I would expect that the Industry would learn a lot from the work done on the new plants and could significantly shorten this time.

MR. DARDEN: That's correct. I mean, these same type of activities would be needed for the new plant analyses and licensing, and there should be some lessons learned from that, hopefully before that would need to be applied to the operating plants. I mean, that's the premise here, that the operating plants would have somewhat longer to deal with this at all, you know, then the new plants. That should be an expectation from hopefully having gone through that first for the new plant activities.

In the potential situation that the interim criteria were implemented on the existing plants, you know, there are a couple of activities here and concerns with that. We've just addressed the methodological item. The current approved methods in most all cases are just not adequate to meet the expected limits that we have seen without some potentially significant effects on the reload core designs, at least for some of the plant fleet. You know, this is not universal, but for some of them there would definitely be some of these issues.

And another item, I think this was also alluded to earlier, the implementation of the interim criteria as it exists would preclude further benefit that may be gained from additional test data that is expected, and some of that data may very well allow relaxation of the current interim criteria.

Another item is really just a resource challenge. Should the Industry for the operating plants, you know, first be required to implement the interim criteria and then potentially perform additional analysis for the final criteria. That could be a real challenge to NRC and Industry resources, so these are some of the reasons we're suggesting the delay for the implementing of the criteria for the operating plants.

The next two slides, and I won't highlight this any longer. The next two slides do indicate some of the particular issues that may exist in having to meet the more restrictive limits. In general, the strategies involve doing things in actual core designs and placement of fuel assemblies that would reduce the rod worths, that would then reduce the severity of the calculated reactivity insertion accident, and the values listed here for some of the plants could involve impacts of ten to 20 percent increase in number of fresh fuel assemblies that do need to be loaded on each batch and potentially either separate from that or in conjunction with that shorter cycle lengths to try to accommodate the same objective.

In the course of loading new additional fresh assemblies, just with limited space and placement in the core, there may be the tendency of needing to load some closer to the core periphery, which would tend to increase the power that's seen in those locations and could cause additional side effects such as increases in vessel fluence, which is a significant materials issue with vessels now in some cases.

CHAIRMAN ARMIJO: Now you distinguish between the impact on the BWRs and PWRs. What's the main reason for that having a greater impact on BWRs?

MR. DARDEN: A more significant impact to BWRs, I don't personally have that information right here. Is there someone else that would comment on why the degree of the effect would be larger?

MR. JAHINGIR: I'm Nayem Jahingir from GNF. For BWR, the criteria, the interim criteria proposes on for core conditions, so BWR kind of -- the startup is limited at the core geo power, and most of our plants should be impacted with this proposed interim criteria.

CHAIRMAN ARMIJO: Okay.

MR. DARDEN: Okay, the next slide shows a few additional items. In loading more fresh assemblies, of course there would be more discharged irradiated assemblies, and that would lead to potentially additional expenses in dry cask storage and just logistics of handling additional fuel assemblies.

The reduced rod worths, which are a desire for meeting the rod ejection issues for BWRS, could reduce some operational flexibility in BWR startup in particular and possible PWR power maneuvering. So, in general, we would anticipate for these potential issues, some of which might be rather costly, you know, minimal benefits in safety of implementing the interim criteria for the operating plants.

In conclusion, there have been some impacts identified that would be associated with implementing the interim criteria. There is a concurrence, I think, with what, from the Industry, with what we believe to be the NRC approach to establish the final criteria, and in conjunction with that it would be helpful once again to have a schedule for implementation defined so that that would give the Industry not just the benefit of the numerical target, which was mentioned earlier of the interim criteria, which we do appreciate, but also some certainty in terms of what the implementing time frame would be that we are also trying to target. In all, this looks like a reasonable balance of resources and safety considerations, but that specified time frame would be very helpful to have.

MEMBER SHACK: But this sort of leaves the, you know, the operating plants with the old criteria, which we kind of all agree are not really right. How about an Industry effort to follow your own criteria as a middle ground?

CHAIRMAN ARMIJO: Technically, in the right direction but not as --

MEMBER SHACK: Technically in the right

direction.

CHAIRMAN ARMIJO: -- conservative as the --

MEMBER SHACK: Not as conservative.

CHAIRMAN ARMIJO: -- as the interim.

MEMBER SHACK: But, you know, it gets away from the current criteria, which are clearly unrealistic.

MR. DARDEN: Correct. No, they are not, but that is something that, you know, could be taken into consideration, I suppose.

MEMBER KRESS: It would be a waste of time unless the NRC staff agrees that that's an acceptable solution.

MEMBER SHACK: Well, they're currently going to accept the current criteria.

MEMBER KRESS: Well, they had to agree to accept that as some sort of --

MEMBER SHACK: Well, this is clearly more conservative than that, so I'm assuming if they're willing to live with the current criteria, they'll live with anything that's more conservative than that.

MEMBER KRESS: Until what?

MEMBER SHACK: Until --

CHAIRMAN ARMIJO: Until the final criteria.

MEMBER SHACK: Until the final criteria

come out.

CHAIRMAN ARMIJO: It's really converging, coming from two different directions.

MEMBER SHACK: I'm just a little concerned that, you know, people are going to be doing power uprates, all those sorts of things that are going on out there manipulating this fuel, and, you know, these guys get to work with something that we universally agree is not right. Now, you know, maybe we can't universally agree on what is right, but it just -- it is a suggestion as an approach.

MR. DARDEN: Okay. The point is well taken for that.

CHAIRMAN ARMIJO: I'm not sure that the staff has said that they are going to -- well, I'm not exactly sure what the staff has said as far as the interim criteria. I'd like to hear it again.

MEMBER SHACK: And operating plants.

CHAIRMAN ARMIJO: What about the operating plants? Is the recommendation from Industry consistent with what you're thinking of doing, or are you just not ready to say? Industry first.

MR. MENDIOLA: Fundamentally, our plan is to apply the interim criteria to the applicants in the design certifications and the COL applicants, and we are well aware of most if not all of these issues that the operating plants have about providing, addressing these criteria to them, as well, and that seems to be the rub is how to do this best and considering all the time tables and not to have this terribly long time period where you have two different sets of criteria between the two different reactors, those being built and those that are currently operating.

We hope to come up with a reasonable solution in our still draft and yet to be issued regulatory generic communication tool here, but we're still wrestling with all the issues that you've just heard the Industry speak of.

CHAIRMAN ARMIJO: So you haven't made up your mind yet? You haven't taken a position yet on when you would apply interim criteria or whether you would wait until there is final criteria ready to go?

MR. MENDIOLA: We haven't had the highest level of buy-in, I guess, is the best way to put it among our management about that. Our position is to staff's position. My branch's position -- let's try it that way -- is to approach it with a -- just to the design certifications and the COL applicants -- sorry, my voice is changing -- and address the final criteria on a -- address the final criteria on a schedule to all plants for the deadline.

CHAIRMAN ARMIJO: But that schedule is yet to be determined.

MR. MENDIOLA: Correct.

CHAIRMAN ARMIJO: Okay.

MR. MENDIOLA: That schedule is yet to be determined.

CHAIRMAN ARMIJO: Okay. I think we know where you stand. Paul, did you want to add anything?

MR. CLIFFORD: He is my boss.

CHAIRMAN ARMIJO: Okay, I got that. All right. All right. So I think that's the best answer we have right now on that, so any other questions from the Committee? From the attendees? Industry?

Well, gentlemen, I think we are finished for the day, and I'd like to thank the staff and presenters from Industry, EPRI, Anatech, and also from Dominion.

MEMBER SHACK: You don't even want to leave a copy your LOCA slides?

CHAIRMAN ARMIJO: Believe me, we've got a lot of LOCA slides. We can always have some more. If you want to leave that, that would be fine. So unless there's any other comments or questions. Okay.

MR. SISK: I want to pick up on the

questions.

CHAIRMAN ARMIJO: Okay. There's a question.

MR. SISK: Yes, this is Rob Sisk with Westinghouse.

CHAIRMAN ARMIJO: Okay.

MR. SISK: And I just want to clarify just for completeness of evaluation that when we talk about a new plant we need to make a distinction or clarification between certified new plants and uncertified new plants. 52.63 finality of design does require some consideration for how they're going to implement these SRP and these criteria for certified designs.

CHAIRMAN ARMIJO: That's a very good point. I think the Committees, this Committee or other Committees, have asked that question before. Does a certified plant really -- that's going to be built, is it subject to the old criteria or the new criteria, and that's something that the staff has to be made clear. I think many in Industry would assume that certified is certified, and that's it.

MR. CARUSO: It depends on what we're certifying.

CHAIRMAN ARMIJO: Well, assuming --

MR. CARUSO: For some of the certified designs, there was nothing certified about the fuel. It was just the fuel was considered to be this product line, and it would be dealt with in the future.

CHAIRMAN ARMIJO: You know, as long as I have the NRR here, I could ask them the question.

MR. CLIFFORD: Yes, fuel design criteria is a Tier 2 star requirement in the DCD process and subject to change. It is kind of a gray area in how you deal with something that was certified, you know, with the understanding that this was in flux, but ultimately, you want to make sure that the system that is being designed, the actual hardware and the NSSS design is capable of mitigating the consequences as an end, whatever the acceptance criteria is.

MEMBER SHACK: I mean, this is a compliance question, right? We have no new requirements here. We're only arguing over what is necessary to demonstrate that you've met those requirements.

MR. CLIFFORD: Well, you know, there's a hurdle to jump when you go backfit. You know, when you're going to send a Commission order to tell somebody they need to change their license, that's a big hurdle to, in a sense, forward fit. I know that's not the correct term, but to address somebody before they have a license issue is a much smaller hurdle.

CHAIRMAN ARMIJO: I totally agree with you.

MR. DUNN: This is Burt Dunn from Areva. It might help you all -- you know, the issue of rod ejection accidents, et cetera, for the PWRs, at least, has been very evidence for some period of time now, and in the advanced reactors or the new reactors coming down the street, at least for EPR, that's been considered.

One of the things, a question asked earlier, was won't you learn from these new ones. Well, as it turns out, the EPR is designed with a loosely coupled core. It's big, and the result of that is much reduced rod work, so it's going to be easier for us to comply with new regulations, and it's probably true for various reasons across the new plant spectrum.

CHAIRMAN ARMIJO: I don't know what the BWR guys would do to just eliminate the rod drop accident, but again a mechanical design might solve that problem rather than all of this stuff.

MR. CLIFFORD: It's kind of a weird situation, because, okay, say you say, "Well, you have a design certification that doesn't need to comply, because it's already frozen. It's designed." Well, two years from now, you issue final, and you do a backfit. This backfit's going to be implemented years before the plant starts up, anyways.

CHAIRMAN ARMIJO: Kind of mind boggling. Well, it's something to think about, and I think it's going to come up again, what the staff position is and the Commission's position is on certified plants.

MR. CLIFFORD: We plan on writing a RIS, and if nothing else, that will force management to at least consider this and agree upon it before it gets, you know, published.

MR. SISK: Rob Sisk, Westinghouse, again. I do want to address -- I think the one question here that goes across the board, whether it's operating plant or certified design, we're talking about an interim criteria here. There is a level of effort that has to go into play every time we have to go back and redo these analyses.

The question becomes do I have to do this for a certified design one, two, three times, and the question is when is the appropriate part? The same for the operating plants that really have to consider when the value in doing these analyses and how frequently these analyses should be done in the interim.

MR. CLIFFORD: You know, on a side note, I mean, the staff has been criticized by the ACRS pretty frequently when we've come in here with a power uprate, and it says 280 calories per gram on it.

MEMBER SHACK: Well, I was just going to warn you that that's going to continue.

MR. CLIFFORD: So, I mean --

MEMBER SHACK: Don't resent that part of the analysis.

CHAIRMAN ARMIJO: We want to have our cake and eat it, too, so that's a problem. Okay, if there are no other comments or questions, I think we've had a good experience.

MR. SCOTT: This is Harold Scott from Research again. I wanted to make the point that we've tried to make sometimes in some of these other meetings that you can either try to squeeze all of the margin out of the criteria, or you can try to sort of squeeze some of the analysis, and we don't think enough effort has been put into the squeezing the analysis part.

You know, I mean, we can probably -- Robbie Montgomery and I can argue for years about cracking and whether the failure criteria or the coolability criteria is X or Y or Z calories per gram, but maybe it turns out that by some simple changes in analysis, 3D kinetics, or even just the way they operate the plants the rod worths aren't going to be that high. Thank you.

CHAIRMAN ARMIJO: Okay. Well, with that, we'll close the meeting, and I thank everybody for their presentations.

(Whereupon, the foregoing matter was adjourned at 1:37 p.m.)