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NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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MATERIALS, METALLURGY AND REACTOR FUELS SUBCOMMITTEE

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THURSDAY

DECEMBER 15, 2011

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ROCKVILLE, MARYLAND

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

SUBCOMMITTEE MEMBERS PRESENT:

J. SAM ARMIJO, Chairman

DENNIS C. BLEY (via telephone)

JOY REMPE

WILLIAM J. SHACK

NRC STAFF PRESENT:

CHRISTOPHER L. BROWN, Designated Federal Official

QUYNH NGUYEN, Cognizant Staff Engineer

WILLIAM RULAND

TARA INVERSO

PAUL CLIFFORD

RALPH LANDRY

GEARY MIZUNO

MICHELLE FLANAGAN

ALSO PRESENT:

TOM RODACK

TOM EICHENBERG

KURT FLAIG

BERT DUNN

GORDON CLEFTON (via telephone)

A G E N D A

P R O C E E D I N G S

(8:30:25 a.m.)

CHAIR ARMIJO: Okay, good morning. The meeting will now come to order.

This is a meeting of the Materials, Metallurgy and Reactor Fuels Subcommittee. I am Sam Armijo, Chairman of the Subcommittee. Members in attendance will be Dr. Dennis Bley, who is on the phone listening in and can make comments when he so chooses. Dr. Bill Shack, Dr. Joy Rempe, Dr. Abdul Said-Khalik will join us in the afternoon, and Dr. Mike Ryan will be cycling in and out.

As you may know, we have a concurrent meeting on the Watts Bar Plant in the next room, so it's going to be a little hectic this morning.

Christopher Brown of the ACRS Staff is the Designated Federal Official for this meeting. Quynh Nguyen of the ACRS Staff is the lead Cognizant Engineer.

The purpose of this briefing is for the Staff to discuss the Draft Proposed Rule Language for 10 CFR 50.46c, the path forward, and potential impacts to industry during its implementation.

We will hear presentations from representatives of the Office of Nuclear Reactor

Regulation (NRR), Nuclear Regulatory Research (RES), and New Reactors.

In addition, presentations will be heard from the Boiling Water Reactor Owners' Group (BWROG) and Pressurized Water Reactor Owners' Group.

The Subcommittee will gather information, analyze relevant issues and facts, and formulate a proposed position and action as appropriate for deliberation by the full Committee.

The rules for participation in today's meeting were announced as part of the Notice of this meeting previously published in the Federal Register on November 23rd, 2011 and revised on December 7th, 2011.

The meeting will be open to the public attendance with the exception of portions that may be closed to protect information that is proprietary pursuant to 5 USC 552(b)(c)(4).

We have received no written comments or requests for time to make oral statements from members of the public regarding today's meeting.

A transcript of the meeting is being kept and will be made available as stated in the Federal Register Notice. Therefore, we request the participants in this meeting to use the microphones located throughout the meeting room when addressing the Subcommittee.

Participants should first identify themselves and speak with sufficient clarity and volume so that they can be readily heard.

A telephone bridge line has been established for this meeting. To preclude interruption of the meeting, the phone will be placed in a listen-in mode during the presentations and Committee discussions. I'd like to ask everyone to please silence all phones, and that includes me, which I just remembered.

We will now proceed with the meeting. I call on Mr. Bill Ruland of the Office of Nuclear Reactor Regulation to make introductory remarks.

MR. RULAND: Good morning, and thank you, Mr. Chairman, and good morning to Subcommittee members.

Before I start, while NRR is taking the lead for this rulemaking, I just want to acknowledge both the Office of Research, and the Office of New Reactors who have worked -- really spent a lot of time with us in developing this rule package, so I'd just like to acknowledge their fine contribution to this rulemaking package.

The purpose of this briefing, of course, is to present the proposed 50.46c Rule package. This proposed rule will eventually replace the existing 40.46 ECCS Rule. And it is not an alternative to the existing requirement, nor is it an optional regulation.

The main objectives of this rulemaking are to capture the research finding which identified new cladding embrittlement mechanisms and to respond to the Commission Directive to develop a more performance-based ECCS Rule.

This rulemaking also responds to two petitions for rulemaking. Both this ACRS Subcommittee and the full Committee have been previously briefed on local research which comprises the technical basis for this rulemaking.

In a letter to the Commission, the ACRS stated that the technical basis was sufficient and rulemaking should proceed.

This briefing -- today's briefing focuses on the proposed rule language and the strategy for implementing the new regulatory requirements on the commercial fleet.

To support the performance-based aspects of the proposed rule, the Staff has developed three new Draft Regulatory Guides. Today's briefing includes a brief summary of these Reg Guides to better understand the connection between the rule language and the Staff Guidance. The ACRS has been previously briefed on these documents and has recommended that the Staff issue them for public comment.

Upon receipt of the local research findings in 2008, NRR completed an initial safety assessment to determine the regulatory path forward. When new information becomes available generally to the Staff which shows that existing regulations may not achieve their intended safety goals, the Staff must decide the speed at which new requirements are imposed upon the industry.

In 2008, the Staff determined that no imminent safety risk existed, and that the rulemaking process should proceed. Recognizing that finalization and implementation of the new ECCS requirements should take several years, the Staff decided that a more detailed Safety Assessment was necessary.

Today's briefing also includes presentations by representatives from the industry and the Staff on the joint effort to confirm and document on a plant-specific basis the continued safe operation of the U.S. nuclear fleet.

As I know Tara and Paul are going to outline, this is really a soup to nuts briefing about the 50.46c rulemaking. Virtually all aspects of the rulemaking will be covered.

So, that concludes my remarks.

CHAIR ARMIJO: Okay. Thank you, Bill. Tara, before you start, I just want to make a double check to make sure that Dennis Bley is still on the phone. Sometimes Skype drops these calls.

Dennis, are you on the line?

MEMBER BLEY: Yes, I am. I'm here. I had to figure out how to unmute my phone.

CHAIR ARMIJO: Okay, thank you very much. All right, Tara, all your's.

MS. INVERSO: Thank you. As Bill mentioned, I'm Tara Inverso, and I'm the Rulemaking Project Manager for the 50.46c Proposed Rule.

The purpose of today's meeting is to present the 50.46c Proposed Rule to the Advisory Committee on Reactor Safeguards. Michelle Flanagan from the Office of Nuclear Regulatory Research will review three associated draft regulatory guides, and then Paul Clifford and Ralph Landry will provide an overview of the Safety Assessment, the NRC audit, and also the implementation of the Proposed Rule.

The meeting agenda for today will begin with this background presentation. Then Paul will walk through each paragraph of the Proposed Rule language. Michelle will then move into her presentation on the regulatory guides. And then the industry will present aspects of the information contained in the Boiling Water Reactor and Pressurized Water Reactor Owners' Group Reports.

Paul will then discuss the NRC's assessment of those reports in the audit, and then Paul and Ralph will talk about the proposed implementation schedules.

This rulemaking has three main objectives. The first objective is to revise the ECCS Acceptance Criteria to reflect research findings. This research program focused on high exposure fuel rod cladding under accident conditions. The research program identified new cladding embrittlement mechanisms and also expanded the NRC's knowledge of previously identified mechanisms.

Specifically, the research pointed to the possibility that zirconium-based alloy fuel cladding could embrittle at a lower combination of temperature and oxygen absorption that currently allowed under the current regulation due to the effects of hydrogen absorption.

Because of this, the Staff has concluded that this rule is necessary to insure the adequate protection to public health and safety by restoring that level of protection which the NRC thought was guaranteed by the current regulation.

Also, through SECY-02-0057, the Commission directed the Staff to while revising the ECCS Acceptance Criteria modify them in such a way that they're more performance-based.

The Commission also directed the Staff to expand the applicability of the rule. And this proposed rule goes to all -- applies to all fuel designs and cladding materials.

As Bill mentioned, the rule also addresses two Petitions for Rulemaking. The first is Petition for Rulemaking 50.71. That was submitted on March 14th, 2000 by David Modine on behalf of the Nuclear Energy Institute, and a request that the NRC expand the applicability of the rule to apply to all zirconium-based cladding alloys, not just Zircaloy and ZIRLO, as mentioned in the current regulation.

The second Petition for Rulemaking that's addressed is PRM-50-84, and that one was submitted by Mr. Mark Lacey on March 15th of 2007, and requested rulemaking in a couple of areas, one of which was that the NRC consider the effects of the thermal resistance of crud and oxide layers in their analyses.

The Staff has had a lot of public interaction developing this rule, the first of which is not noticed on this slide, but on July 31st of 2008 the NRC published the regulatory basis for this rule, which was summarized in Research Information Letter 0801, and the details of which was really in NUREG/CR-6967.

The NRC had a public meeting on that regulatory basis on September 23rd, 2008 to discuss the public comments received on the technical basis. The Staff presented the technical basis to the ACRS in December of 2008, and on December 18th the ACRS wrote a letter stating that there was sufficient understanding and data to proceed with the rulemaking.

So, on August 13th, 2009 the NRC published the Advance Notice of Proposed Rulemaking, and that laid out the four objectives of the rulemaking, and also posed 12 questions for specific response. The NRC received 19 comment letters in response to the ANPR from a variety of sources, the industry, international community, and some public citizens.

There was a public workshop held between

April 28^{th} and 29^{th}, 2010 to discuss the ANPR comments. The ANPR comments and the NRC responses were discussed on April 28^{th}.

The purpose of the April 29^{th} public workshop was to introduce the concept of a prospective generic letter that would address the potential embrittlement of fuel rods during loss of coolant accidents.

It was during that public meeting that the industry presented a concept by which that information would be provided through a voluntary initiative. So, public meetings were held on August 12^{th} and December 2^{nd}, 2010, and then again on March 3 rd, 2011 to work with the industry to make sure that that information provided in that report was similar to that that would be requested through a generic letter.

We've also had several meetings with the ACRS. We already mentioned the meetings on the regulatory basis. In June and July, Michelle presented a technical document called "The Mechanical Behavior of Ballooned and Ruptured Cladding," and that addressed the applicability of the hydrogen-based embrittlement correlation to areas of the fuel rod which may rupture. And that technical document will supplement RIL-0801 for the regulatory basis in that region of the rod.

In May and June, we also presented the three Draft Regulatory Guides to ACRS Subcommittee and full Committees.

During the May meeting, we listed a slide of things that we were considering along with this rulemaking, and one of the topics listed was fuel fragmentation, relocation, and dispersal. And we committed to ACRS that we would follow-up with our final determination of how that would be addressed through this rulemaking.

The Staff's conclusion is that further research is necessary to understand fuel dispersal and its significance, so it is not included in this proposed rule.

The NRC Staff is recommending to the Commission that the Commission do, indeed, publish this proposed rule for comment. This proposed rule is complete, and it's current written addresses all of the Commission direction and all of the original rulemaking objectives.

CHAIR ARMIJO: So, Tara, can I conclude that as far as the Staff is concerned there is no serious deficiency in the Proposed Rule by leaving out the issue of fuel dispersal?

MS. INVERSO: Right. And the current understanding of that phenomena is not complete to even include it at this point. We don't know whether or not it would needed in a regulation. Further research is needed to determine that. But the rule is complete. There aren't any holes at this point.

CHAIR ARMIJO: Okay, thank you.

MS. INVERSO: The current rulemaking schedule, return to the full Committee of the ACRS on January 19th, 2012. And the rule is due to the Executive Director for Operations on February 29th, 2012.

Are there any questions?

(No response.)

(Off the record comments.)

MR. CLIFFORD: Good morning. My name is Paul Clifford. I work in NRR, and I am the Technical Lead for the 50.46c Rulemaking. My presentation will focus on the 50.46c Rule, its purpose, its structure, and its basis.

The design function of the Emergency Core Cooling System is to mitigate the consequences of a postulated loss of coolant accident. Specifically, the performance objectives of the many systems, structures, and components that comprise the ECCS is to replenish the liquid inventory lost out the break in order to maintain core temperatures at an acceptable level.

This slide provides a regulatory definition of a loss of coolant accident. A LOCA means a hypothetical accident involving a break in the primary system piping which results in a loss of RCS coolant beyond the capability of the reactor makeup system.

The accident progression of a primary system piping break consists of a loss of RCA liquid inventory, depressurization of the primary system, and a consequential heat up of the fuel rods. The rate of change in these parameters depends strongly on the break size and the break location.

This figure illustrates a predicted fuel rod cladding temperature during the initial phase of a double-ended guillotine break in the cold leg of a CE two-loop PWR. Water injected into the primary system initially via the safety injection tanks and then via safety injection pumps re-establishes core liquid level and turns around the cladding temperature excursion.

For this case the principal performance goal of the ECCS was achieved since core temperatures were maintained at an acceptable level as defined by the current regulation at 2200 degrees Fahrenheit peak clad temperature.

CHAIR ARMIJO: Paul, before you leave that, this is for a large-break LOCA.

MR. CLIFFORD: This is a large-break LOCA.

CHAIR ARMIJO: Now, what's the time scale for a small-break LOCA? What's a range -- what are we talking about typical, not that there is anything typical but just for perspective. Are we talking about several thousands of seconds? What kind of peak temperatures just roughly?

MR. CLIFFORD: I'll look to our LOCA system expert.

MR. LANDRY: Mr. Chairman, this is Ralph Landry from the Office of New Reactors.

The time scale for a small-break LOCA is very large spread because of the size of the break. It can be from hundreds of seconds out to thousands of seconds. A typical break, such as a two-inch break, is going to be about a 3,000 second event, about an hour's event.

CHAIR ARMIJO: Okay. And the temperature is --

MR. LANDRY: Temperatures in a small-break typically do not reach the kind of temperatures they do in a large break.

CHAIR ARMIJO: Right. But that's --

MR. LANDRY: A high-temperature small-break would be probably on the order of 1600 degrees Fahrenheit.

CHAIR ARMIJO: Okay.

MR. LANDRY: But the small break has a tendency to oxidize a great deal because you're staying up a moderately high temperature for a very long period of time.

CHAIR ARMIJO: Yes, that's what I was trying to get at, is the breakaway oxidation issue. And it's my understanding that above 800 degree Centigrade is where this really kicks in.

MR. LANDRY: That's correct.

CHAIR ARMIJO: And below that we're not particularly concerned, or are we?

MR. LANDRY: Paul is going to get into what we've put into the regulation, proposed regulation on breakaway oxidation. And if we get into talking about the total package, one of the questions -- one of the concerns we have is that fuel vendors can demonstrate that the timed breakaway oxidation is longer than the time that they would predict a particular plant would stay above our at the breakaway temperature.

CHAIR ARMIJO: Okay.

MR. LANDRY: So, we're relating the two through the total package that supports this rule.

MR. CLIFFORD: Right. And you'll see this afternoon that 103 of the power plant predict time above 800 at less than 2,000 seconds.

CHAIR ARMIJO: Okay.

MR. CLIFFORD: Whereas, the breakaway oxidation usually occurs at around 5,000 seconds.

CHAIR ARMIJO: Okay.

MR. CLIFFORD: So, it's not -- it turns out that it's not that challenging.

CHAIR ARMIJO: Okay. Thanks, Paul.

MR. CLIFFORD: The existing 50.46 Rule dictates prescriptive analytical limits with no defined performance objective. To achieve the Commission Directive of a more performance-based regulation, the working group essentially started with a blank sheet of paper. As a result, 50.46c represents a major restructuring of the rule. In a side-by-side comparison you wouldn't even know it was the same regulation.

This slide shows kind of the Table of Contents for the rule. It's important to note that the existing rule was limited in applicability to the LWRs fueled with uranium oxide pellets within cylindrical Zircaloy or ZIRLO cladding. So, legally, there was no ECCS regulatory requirements for licensees opting to use more advanced claddings that weren't covered under the umbrella of Zircaloy or ZIRLO. Further, there were no regulations governing the performance of any new cladding material during a LOCA.

So, the first step in the development of 50.46c was to define an expanded applicability. The new rule is meant to be universally applicable to all LWRs independent of ECCS design, independent of fuel design.

The second step in the development of 50.46c was to define kind of the tier one principal ECCS performance objectives. However, since the performance of the ECCS will be judged on how well the fuel holds up under LOCA conditions, specific fuel design-dependent performance requirements must also be defined.

I mean, it's logical to think that specific performance requirements of the current generation of fuel which is ceramic UO2 pellet within metallic Zircaloy cladding would be different than what the specific performance objectives would be for say a metallic thorium-plutonium pellet within a ceramic cladding.

Therefore, the capacity and the capability of the ECCS may differ based on the type of fuel for which it is trying to cool. However, the principal requirement, the tier one performance objectives would still be universal.

The third step in the development of 50.46c was to define the specific fuel design-specific requirements for the current generation of fuel.

Regulatory requirements for the ECCS consist of, one, principal performance objectives which are to maintain acceptable core temperatures during a LOCA and to remove decay heat following a LOCA. In addition, there are principal analytical requirements.

Simply put, each LWR must be equipped with an ECCS capable of satisfying the principal performance objectives, and each licensee must provide a performance demonstration showing compliance.

For each fuel design the rule must specify specific performance requirements and analytical limits which form the basis of the acceptable core temperatures, because an acceptable temperature for one fuel is going to be different than an acceptable temperature for a different fuel. And these must be established based upon the degradation mechanisms and any other unique features specific to that fuel design. In addition, specific analytical requirements which impact the predicted performance of the fuel under LOCA condition must also be defined.

CHAIR ARMIJO: I just want to make sure I understand this, Paul.

MR. CLIFFORD: Sure.

CHAIR ARMIJO: Take a Westinghouse 17x17 fuel assembly with ZIRLO cladding. If either the vendor does sufficient work to define these specific performance requirements and analytical limits, is that applicable to all PWRs that use that fuel or to a subset of PWRs that use that fuel?

MR. CLIFFORD: It would be applicable -- it's really material-specific, but there may be fuel design specific analytical requirements which need to be considered based on the design of the fuel.

I guess what we're trying to say here is you need to make it universal. For instance, we have a wealth of information through all the testing that's been done for the last 30 years, and especially all the data we received from the high-burnup LOCA research program at Argonne on zirconium. So, we know all -- we've identified all the degradation mechanisms, and we've defined a regulatory performance objective, and that is to maintain ductility, because we know for that cladding material we want to maintain ductility. And we have a sufficient empirical database where we define what impacts the degradation and ductility. But for say a ceramic cladding, there is no inherent ductility, so we wouldn't use ductility as a performance metric. We would have to define another performance metric, maybe just strength. And then we would have to identify any degradation mechanisms that occur under LOCA conditions which affect its strength.

CHAIR ARMIJO: Okay, so this much broader than just zirconium-based alloys.

MR. CLIFFORD: That's why it's universal. But they all relate to temperature. That's how we are able to define overall performance objectives; maintain an acceptable level. But the acceptable level is then defined by the experimental database on that particular material.

And we'll be getting into that for the current generation, so I think it'll be more clear as we walk through it. Actually, it's on some of this slide right here.

For the current fuel designs which consist of uranium oxide or a mixed uranium-plutonium oxide within zirconium alloy cladding, 50.46 defines these specific performance requirements and analytical requirements based upon our extensive experimental -- our empirical database.

For new designs, additional research may be necessary to identify all degradation mechanisms and any unique features. New performance objectives, analytical limits, and analytical requirements would need to be established based upon the research findings on any new fuel design.

CHAIR ARMIJO: And I just want to know how much flexibility do you have with current fuel designs and current fuel cladding materials? For example, you have a ZIRLO and an optimized ZIRLO, and maybe there'll be in the future a really super optimized ZIRLO. It's basically a zirconium-based alloy with some tweaking. Would that fall under your current fuel design definition, or would you consider that a new fuel design?

MR. CLIFFORD: We have guidance which has been developed which addresses how do you validate that a new zirconium alloy falls under the umbrella of what has been tested in the past.

CHAIR ARMIJO: Okay.

MR. CLIFFORD: So, there would be a required test program for any new zirconium alloy to either define new analytical limits, or to show that it falls under the umbrella of the previous extensive zirconium database.

CHAIR ARMIJO: Okay.

MR. CLIFFORD: And that's provided in a Reg Guide. And Michelle will be discussing that later on somewhere.

CHAIR ARMIJO: All right.

MEMBER REMPE: And there's guidance if someone comes in with something totally different to help them start, because basically you're saying new performance objectives limits and requirements will need to be established based on the research that a new design would come in, and how would they interact to -- could you elaborate on how they'd interact to come up with the new requirements like some of these ceramic cladding --

MR. CLIFFORD: Right.

MEMBER REMPE: -- that are being proposed?

MR. CLIFFORD: That's a great question. We can't define what the performance objective is for a new material without first testing the new material.

MEMBER REMPE: Right.

MR. CLIFFORD: And we can't define what the analytical limit on temperature may or may not be to insure that you meet your performance objective until you've actually tested the material. So, it's almost impossible to write -- the guidance would be just so general.

I think what we would expect is they would look at the guidance for zirconium, and they would follow the logic on what was done, how it was interpreted, how you defined your performance metric, and then how you defined analytical limits to insure that you met your performance objective.

CHAIR ARMIJO: But they'd have the obligation to look for degradation mechanisms that are different than existing zirconium alloys. They'd have to look for something that's unique to their particular material.

MR. CLIFFORD: Exactly, because our tests are set up to measure ductility. Like I said, ceramic you wouldn't have ductility, so you wouldn't even -- I mean, you would never use those tests specifically. But the concept of how do I insure that the fuel performs in an acceptable manner, you would have to define what an acceptable manner is; whether it's a retention of fission gas, the retention of fuel pellets, or an overall coolable geometry. And then you would have to show that you maintained temperatures below whatever limit you define based on your experiments to insure that you maintain that acceptable behavior. And that's really what's meant by truly performance-based.

MEMBER SHACK: But, I mean, they would have to develop all that information.

MR. CLIFFORD: Yes.

MEMBER SHACK: Then you would have to write a new section of the rule.

MR. CLIFFORD: Absolutely.

MEMBER SHACK: You're going to --

MR. CLIFFORD: Absolutely. You can see from this slide in Paragraph G we're defining the specific requirements to maintain, for one particular instance, ductility for zirconium, and all the analytical limits associated with temperature to preserve ductility. But Paragraphs H, I, and J are reserved, so if someone came in with a ceramic cladding then we would have to work through their experimental database, maybe run confirmatory testing, develop the regulatory envelope around which we would license the new fuel, and how it behaved under LOCA conditions, and then define analytical limits and then go to rulemaking.

CHAIR ARMIJO: Okay.

MR. CLIFFORD: In the next section I will walk through the rule language and discuss the regulatory and technical basis of each paragraph.

Paragraph (a). As I mentioned earlier, one of our objectives was to expand the applicability and to make the rule universally applicable to all ECCS system, and all fuel designs. This paragraph achieves the objective to expand the applicability to all plants, and especially to remove the burden of Zircaloy or ZIRLO only. And this eliminate the need for exemptions.

We issued dozens of exemptions for M5, and more recently for optimized ZIRLO, so this change in the structure of the rule will eliminate those exemptions.

Paragraph (b) simply adds the definition of breakaway oxidation which was new embrittlement mechanisms identified by the LOCA research program and included in this rule.

Paragraph (c) is the relationship to other regulations. The first thing you'll notice is there's gray text and there's black text. And I think was also included in the rule language that was provided to the ACRS staff.

Gray indicates that it's unchanged from the current regulation. We may have moved it, but the text itself is unchanged, so when you see anything in gray that means it's the same as the current 50.46. And all we did here was just to clarify that ECCS valuation models must be approved by the Staff.

CHAIR ARMIJO: Okay.

MR. CLIFFORD: Paragraph (d) is the Emergency Core Cooling System Design. These are the principal design requirements for any ECCS system. Section (1) of the paragraph defines these performance objectives and states that all LWRs must satisfy these performance objectives.

The two principal performance objectives are that core temperatures remain below defined fuel-specific analytical limits. And that the ECCS system have sufficient capability to remove the decay heat from long-lived radioactive isotopes.

Very general in nature, really it's very general in nature but the specifics come when you analyze the fuel, because you are judging the performance of ECCS on how well the fuel holds up under LOCA conditions.

Okay, item (2) of the section requires that all licensees perform a compliance demonstration, and that they're allowed to use either a realistic model or an Appendix K model. And these requirements are consistent with the current 50.46, as you can see from the gray text.

Now, embedded in the analytical requirements for ECCS are that --

CHAIR ARMIJO: Paul, just to go back. So, when the licensee performs its performance demonstration document or evaluation, does that -- will that be submitted to the Staff, reviewed and approved by the Staff? And that's plant-specific?

MR. CLIFFORD: Absolutely.

CHAIR ARMIJO: Okay.

MR. CLIFFORD: Although you see the first part of the paragraph is in black, so it's new.

CHAIR ARMIJO: Yes.

MR. CLIFFORD: It was always understood, but it wasn't legally documented.

The next analytical requirement is that factors which impact the predicted core geometry and coolant flow be included in the evaluation model. And these would be fuel-specific factors which would be defined in subsequent sections.

CHAIR ARMIJO: Here's where I get confused. We want to maintain coolable geometry.

MR. CLIFFORD: Yes.

CHAIR ARMIJO: But we don't have a measure, a direct measure of what a coolable geometry is. So, as a surrogate for that we use a ductility parameter. And, first of all, is that really accurate what I just said, or --

MR. CLIFFORD: Well, ductility is a favorable material property that provides a level of assurance that the fuel rods won't shatter during quenching, and that the fuel rods and the fuel will stay as they were. They're in a geometry which is, I shouldn't say simple, but I'm going to use the word simple to model and to analyze, and to demonstrate with high confidence that you can show that temperatures stay below 2200 degrees. So, any change in that geometry would introduce a lot of uncertainty into your compliance demonstration. So, by maintaining ductility you're saying that you're maintaining rods in their existing rod lattice array, and that that rod lattice array can be shown with high confidence to be coolable.

CHAIR ARMIJO: But having some fuel fracture break, there's got to be an acceptable amount of damage to the core while it's still very coolable, but you don't have a position on that. You just --

MR. CLIFFORD: No, this paragraph basically says that if you predict any changes in geometry, and I can give you two examples for current fuel designs. The first would be if because the RCS pressure is dropping so quickly and you have high rod internal pressure and the cladding temperatures are getting high, you creep out, and you balloon and burst fuel rods. You have to specifically model the fuel that balloons and bursts, and that would be dictated in a subsequent fuel-specific.

Another example would be that if the loads applied to the structure of your fuel assembly were to cause degradation; in other words, you were to break grid straps and the fuel rods would -- the fuel rod lattice array would deform, then you would need to specifically model that.

CHAIR ARMIJO: Okay, let's --

MR. CLIFFORD: So, you are taking that into account.

CHAIR ARMIJO: If someone says okay, look, during the quench there's enough either bending stresses or tensile stresses on the assembly that -- and this is already oxidized cladding. I'm going to break the cladding in let's say the peak temperature region, and I'm going to break some of the rods. I don't know how many but let's pick a number, and they -- but it breaks and the pellets don't fall out. I mean, it's just not a double-ended guillotine where pellets pour out, but it just simply breaks, but the geometry is maintained.

Now, if they came to you with an analysis showing hey, that's the worst that can happen, what then? Do they have to do that, or do they -- or do you say I really don't care as long as you have adequate ductility in your cladding?

MR. CLIFFORD: Well, we've done some research where we tried to evaluate or quantify the mechanical properties in the balloon burst region, for instance. And at the end of the day, we're maintaining the same regulatory approach or regulatory position that it's difficult to quantify all of the stresses of loads that are applied on fuel during a LOCA. So, if you were trying to say that only so many rods would break, you would then have to truly understand all the loads that could be applied during a LOCA.

You can't have a strength-based criteria unless you understand what the strength requirements are. But we fall back to ductility because it's a favorable property that provides a high level of confidence that --

CHAIR ARMIJO: You'll never get a metallurgist to argue against ductility, but what we're just trying to get a sense of --

MEMBER SHACK: But looking at it here, I mean, your high level requirement is, in fact, your coolable geometry.

MR. CLIFFORD: Correct.

MEMBER SHACK: For the Zircaloy alloys your specific requirement is the ductility requirement, which certainly does insure the coolability. You could argue that it also provides some defense-in-depth; that is, it's certainly possible to make arguments as Sam did that even if you lost ductility, you wouldn't have lost coolable geometry. But as you say, that's a much more complex argument. But that is one level down from the rule. The rule high-level requirement as I see is coolable geometry.

MR. CLIFFORD: But then we specific that fuel-specific is ductility.

MEMBER SHACK: Right. The fuel-specific is ductility.

MR. CLIFFORD: So, if someone wanted to come in and say we're not going to maintain ductility, but we're going to alter our performance metric, then that would be either -- that would be an exemption. You'd have to issue an exemption.

CHAIR ARMIJO: They'd have to --

MR. CLIFFORD: The burden of proof would be on them --

MEMBER SHACK: Right.

MR. CLIFFORD: -- to demonstrate why that was acceptable.

CHAIR ARMIJO: Why this is coolable even though their ductility isn't 1 percent, it's half a percent.

MR. CLIFFORD: Right.

CHAIR ARMIJO: Or some other number. Okay.

MR. CLIFFORD: This paragraph provides the analytical requirement related to identifying the most limiting combination of break size and location. It remains largely unchanged from the current regulation.

New text has been added to clarify that the existing requirements, that the demonstration must cover the entire duration of the transient.

This paragraph simply provides a pointer to the new analytical requirements for current fuel designs from subsequent paragraphs.

Section (3) under Paragraph (d) is largely unchanged. Essentially, we move the documentation requirements from Appendix K into the main body of the rule so that they would be applicable to both Appendix K and realistic models. And the last section here is a pointer to the implementation schedule.

CHAIR ARMIJO: Okay.

MR. CLIFFORD: Paragraph (g) specifies performance requirements and analytical limits used to judge ECCS performance for current fuel designs. And those current fuel designs are uranium oxide or mixed uranium-plutonium oxide within cylindrical zirconium alloy cladding.

Peak clad temperature is the first of five fuel temperature analytical limits associated with the ECCS principal performance objective in Paragraph (d)(1)(i) which is to maintain an acceptable core temperature. So, we've defined five temperature requirements under the heading of acceptable core temperature.

With respect to PCT, research confirmed that there is rapid embrittlement above 2200, so the 2200 degree upper limit is being maintained. PCT also prevents runaway oxidation in high temperature failure but is governed by cladding embrittlement based upon the research findings.

Paragraph (g)(II), Cladding Embrittlement.

This paragraph defines the preservation of cladding ductility as a performance objective. It is consistent with the current regulatory requirements. This paragraph captures the research finding which is a new embrittlement mechanism that was referred to as hydrogen-enhanced beta-layer embrittlement. This paragraph requires the use of an approved analytical limit on PCT and integral time at temperature based on an approved experimental technique.

The Staff has developed Reg Guides which provide acceptable analytical limits for licensees who do not want to run further testing on the current zirconium alloys. In addition, the Staff has developed a Reg Guide which provides an acceptable experimental technique for conducting post-quench ductility tests if they choose to refine the Staff's analytical limits, or for newer alloys.

Paragraph (iii), Breakaway Oxidation. This paragraph captures the new embrittlement mechanism identified by the high-burnup LOCA research program. It requires the use of approved analytical limits on breakaway oxidation based upon an approved experimental technique. And we have developed a Reg Guide which provides an acceptable experimental technique for defining analytical limits for each zirconium alloy.

Paragraph (iv), Maximum Hydrogen Generation. This paragraph limits the generation of combustible gas, which in the case of zirconium is -- the zirconium water reaction is hydrogen, and remains unchanged from the current regulation.

CHAIR ARMIJO: For some reason this is not in gray.

MR. CLIFFORD: Oh. I'm not sure why it's not in gray. It's word-for-word. Oversight.

CHAIR ARMIJO: That's okay.

MR. CLIFFORD: The last fuel temperature analytical limit relates to long-term cooling. The current 50.46(b)(5) paragraph states, "After any calculated successful initial operation of the ECCS, the calculated core temperature shall be maintained at an acceptable low value and decay heat shall be removed for the extended period of time required by the long-lived radioactive activity remaining in the core. However, there are no performance requirements or analytical limits which defines acceptably low value."

For 50.46c, the working group has decided to use the preservation of cladding ductility as the performance metric, same as during the initial stages of the LOCA. The Federal Register Notice includes specific requests for comment on this topic.

CHAIR ARMIJO: Has anyone satisfied that requirement, as far as you know? Is it currently satisfied?

MR. CLIFFORD: In some of the analysis that I'm familiar with, it's done differently. They're concerned about boron precipitation and how it affects the circulation. But generally if you look at long-term cooling, they show that the core liquid level --

CHAIR ARMIJO: Is covered.

MR. CLIFFORD: The core is covered.

CHAIR ARMIJO: Okay.

MR. CLIFFORD: And they do heat balance to show that the rate of circulation matches or exceeds boil-off. This would require that they define a temperature which is associated to a favorable material property. Here we're saying ductility, we're maintaining the ductility theme. And we've asked questions of whether this is -- is this the right performance metric for long-term cooling? Should we be looking at some other performance metric? Is there an analytical limit already established? Has the industry already done testing which has defined a new analytical limit for long-term cooling?

CHAIR ARMIJO: Well, if you went back to your figure where you show the LOCA transient.

MR. CLIFFORD: Sure.

CHAIR ARMIJO: And you get out to those 500-600 seconds, okay, that one there. And now your clad temperature is down to what, somewhere around 1,000, but it's already been embrittled due to transient, but it's been demonstrated that the cladding ductility is acceptable at that point.

Now, it just keeps -- it's still being cooled, and the core is covered. Isn't that sufficient for a definite period of time? I mean, is there any other mechanism going on that the embrittlement precedes?

MR. CLIFFORD: In general, when you bring a material up in high temperature, especially when you go above your phase transition temperatures, and then you quench it rapidly, you freeze the micro structure in a non-equilibrium condition. And it generally has strength but it lacks ductility.

If you then subsequently age the material, you generally improve ductility as you're allowing the micro structure to change. But that's general. We don't have specific tests where we've heated up cladding, quenched cladding, and then gone through subsequent heat up cycles to find out if there is some other mechanism that's occurring which is affecting ductility. We don't have those tests.

There are tests out there where they've taken cladding and they've put it in an autoclave under steam environment for a long period of time, and they're looking for really corrosion properties. Is there nodular corrosion that's occurring? Is there hydrogen uptake that's occurring, and how that affects ductility. But that's a different embrittlement mechanism than simply oxygen ingress into the micro structure.

CHAIR ARMIJO: This is so diffused, so how can anyone meet that requirement, though, Paul? Are you -- right now this is just something going out for comment? Is it something that the Staff feels yes, we've got to have some requirements there for that?

MR. CLIFFORD: We believe there needs to be -- in a true performance-based rule, you have to define what you're trying to protect. What's the performance metric, and then how do you achieve that metric?

Right now, the rule just says an acceptably low temperature, but it doesn't say what an acceptably low temperature is. It's understood -- it was understood that you go through a quench, temperatures continue to go down and you stay at a very low temperature, close to normal operating temperatures like 700 degrees Fahrenheit. But it's not written down that way.

So, in theory you could have a second, I shouldn't say transient, but if you have boron precipitation concerns and you have to change your injection point, maybe you have a small heat up that occurs during cold-leg to hot-leg injection swap-over and what's an acceptable temperature for them to then escalate to during that operation or maneuver?

CHAIR ARMIJO: But let me just --

MR. CLIFFORD: It's just not defined.

CHAIR ARMIJO: -- make it real simple. Let's say you finish up at 500 seconds. Your clad temperature is down -- back down to about 1,000 degrees F, and it sits there for 70 hours, 100 hours long-term, aren't you finished, or do you have to do more testing? I mean, what's --

MEMBER SHACK: Well, suppose we had something like that we talked about yesterday where they're going to be switching the boron injection and they've got three minutes to do it, so it doesn't heat up again. And the three minutes I think is determined on 2200 F, and the question is --

CHAIR ARMIJO: They see themselves going up again?

MEMBER SHACK: Yes.

CHAIR ARMIJO: Cycling between --

MEMBER SHACK: Because you're turning off the coolant.

CHAIR ARMIJO: Okay.

MEMBER SHACK: And it's going to heat up. And you say it's going to do your -- so you have a limit of three minutes. I don't know, if they do it in two minutes it gets to 1600 F or something. And they're going to do that every 16 hours.

CHAIR ARMIJO: I could see that, you know, where you're actually raising the temperature back up again or thermally cycling it, or doing something that changes the cladding temperature dramatically in the wrong direction. But just if they -- if it just sits there and --

MR. CLIFFORD: If it sits at a low temperature everybody believes it's going to be fine, but it's this perturbation --

MR. LANDRY: Paul, this is Ralph Landry from NRO. The plant will not come down to 1000 degrees in a large-break LOCA and then just sit there. This is the point at which quench is going to occur, and the temperature of the cladding is going to drop down to about 200 degrees. This curve just ends at this point. This isn't going through the full quench.

Now there's going to be a full quench, and what we're concerned about is codifying what is not in the regulation today with regard to long-term cooling that has come out through the GSI-191 resolution program. And there when -- even though you've quenched the core and the core is covered, the core is not covered water solid. There's still two-phase mixture and there's still boiling going on in the core during this long-term period.

And our concern with GSI-191 was that you not reheat the core beyond the point at which there were data that showed the cladding would not be further embrittled. That's where the 800 degree Fahrenheit number came from.

When we talked about putting that in this regulation, we realized that the data supporting that 800 degrees were proprietary, so we could not put into the regulation proprietary information. So, that's why we came up with the wording that we have in this paragraph, that you have to come in with a supportable number for the reheat up of a core if you get blockage or any reason that impedes your long-term cooling of the core.

Today the plants through the GSI-191 program are being shown to meet the stated goals, but we wanted to codify it in the regulation now instead of a simple statement provide long-term cooling. Does that help explain what's behind this?

CHAIR ARMIJO: I think I understand it and I just have to wait and see what the public comments are on this thing. It's hard for me to understand that -- a rule where really there's no specific or demonstrated way of saying you've satisfied that rule.

For example, in this particular event it's still not down to 200 or it's not down to boiling at one atmosphere. But if it -- unless it goes up in temperature over where it is at the end of the transient, shouldn't you be finished? Isn't that enough? And I get the feeling that you don't really know that you're finished, that you've satisfied the requirements.

MR. CLIFFORD: Well, I mean, the requirement is that you're able -- the ECCS has a capability of a removing heat for a long period of time because you have decay heat that goes out --

CHAIR ARMIJO: Right, but it's --

MR. CLIFFORD: -- 30 days or beyond, so you need to show that you can maintain recirculation and remove the heat out to 30 days or beyond. And if there is a subsequent heat up for whatever reason, there has to be a codified performance metric. Why is it acceptable to go back to 1,000 degrees? Why is it acceptable to go to 1,200? Why is it acceptable to go back to 2,200? We don't think 2,200 is the right number, that you shouldn't have --

(Simultaneous speech.)

CHAIR ARMIJO: No, you're not going to get an argument with me on that, but I'm just -- and I can see situations where actually the clad temperature increases again. You know, that's an undesirable thing because it's already in a poor state. But if you're actually -- you've stabilized temperature and it's either constant or dropping, when are you finished, and what's an acceptable answer to this --

MR. CLIFFORD: I believe right now it's 30 days.

CHAIR ARMIJO: Okay. So, if you maintain temperature at or below the temperature at the end of the transient for 30 days, you're finished?

MR. CLIFFORD: Well, you're trying to maintain inventory in your --

CHAIR ARMIJO: Of course, you --

MR. CLIFFORD: Temperature is down and you match boil-off rates, so you're always keeping it cool and keeping it covered. That's what --

CHAIR ARMIJO: Okay. Well, look, I've got to think about it some more, but I think that helps.

MEMBER SHACK: But coming back to Ralph's thing, you then have a requirement for the maximum temperature that it can reach during that 30 days as part of the GSI-191?

MR. LANDRY: That was the performance metric that we used during the review of the WCAP on core blockage because that was the only performance metric that we had that was supported by data. Now, we didn't say that it would be impossible to support going to a higher temperature than 800. There were just no data that showed that you could support a higher temperature. And during some of the discussions on the WCAP-16793 resolution we had said you want to go for a higher temperature, you have data to support it. And these were the only data that supported that temperature so we said okay, that's the limit.

MR. CLIFFORD: And you're probably going to have a different embrittlement mechanism which is probably going to be nodular corrosion as opposed to the 2,200 which is different.

MR. LANDRY: And that's what we're saying in the rule, this proposed language. Come in with supportable analytical basis.

CHAIR ARMIJO: Okay.

MR. LANDRY: That's what makes it performance-based.

MR. CLIFFORD: Right.

MEMBER REMPE: Is the 30 days specified somewhere in a Reg Guide, or where did that come -- where does that show up at?

MR. CLIFFORD: Ralph, do you know the historical basis for the 30 days?

MR. LANDRY: I'm sorry?

MEMBER REMPE: Where is the 30 days specified, is it in a Reg Guide, or where would they find the time?

CHAIR ARMIJO: Could you repeat that?

MEMBER REMPE: Well, there's been mention of 30 days, and I just wondered where that was documented.

MR. LANDRY: It's not in the regulation.

MEMBER SHACK: Is it Reg Guide 1.82?

MR. LANDRY: It could be in 1.82. I'm

trying to recall where that number comes in. It's like one of those urban legends.

MR. RULAND: Could we do -- we'll do some research on that --

CHAIR ARMIJO: Okay.

MR. RULAND: -- and try to -- and provide an answer subsequent. Okay, Tara?

CHAIR ARMIJO: Thanks, Paul.

MR. CLIFFORD: Okay. The next Paragraph (g)(2) defines the fuel-specific analytical requirements for the current generation of fuel. The first item captures the research finding that oxygen ingress from the cladding ID surface promotes cladding embrittlement and reduces the allowable time at temperature to nil ductility. And the way it's worded it really is performance-based. If you can show there's an oxygen source, you must consider it.

The second fuel-specific analytical requirement relates to crud and oxide layers, and the effect on initial stored energy. The addition of this paragraph achieves one of the rulemaking objectives which is to address the petition we received from the public.

Paragraph (k), Use of an NRC-approved fuel in the reactor. This paragraph clarifies the existing requirement on use of NRC-approved fuel designs for which specific ECCS performance requirements have been established and demonstrated. It also recognizes the importance of lead test assemblies for collecting irradiated data to support the NRC review and approval of new fuel designs.

Paragraph (l), Authority to impose restrictions on operation. This paragraph is not new, but it has been expanded to identify that there is two offices within the NRC, the NRR which affects Part 50 licensees, and NRO which addressees Part 52 licensees.

Paragraph (m), Reporting. The language in Paragraph (m) has been significantly upgraded from the existing regulation. However, there's been no change in the intent or the requirements of this section. What we were trying to accomplish is to clarify the existing requirements because this has been a source of confusion in the past.

Paragraph (m)(2), with respect to reporting the definition of a significant error or change to an evaluation model has been expanded to include 0.4 percent ECR as a threshold in addition to the existing 50 degree Fahrenheit change in peak clad temperature.

CHAIR ARMIJO: What is the basis for that

0.4? Why isn't higher, why isn't it lower?

MR. CLIFFORD: 0.4 equates to roughly a change of 50 degrees Fahrenheit up at around 2,100 degrees Fahrenheit. If you were to change --

CHAIR ARMIJO: For any zirconium-based alloy?

MR. CLIFFORD: Correct.

CHAIR ARMIJO: Okay.

MR. CLIFFORD: The thought here was if you change something in the evaluation model which resulted in prolonging the transient but not necessarily changing the peak clad temperature, previously we wouldn't be able to evaluate that. But by providing both a peak clad temperature and a integral time at temperature that you would capture changes which would affect both the peak and the prolonged nature of the transient.

CHAIR ARMIJO: And the way it's written right now in the rule, this 50 degrees at the .4 ECR would not only be a single change, but an accumulation of changes over time.

MR. CLIFFORD: It's the absolute --

CHAIR ARMIJO: In the original analysis, I guess.

MR. CLIFFORD: Some of the absolute

changes. So, if you had a -20 degree Fahrenheit change and a +40 degree change because you discovered two errors then that would be beyond a summation of the absolutes, so it would be more than 50, even though if you added them directly it would be 20. And that's the way the current regulation is working.

CHAIR ARMIJO: And the purpose of that reporting is to find out that there's some deficiencies in the way the thing is modeled, or that the material really is much more susceptible to fracture than you believed.

MR. CLIFFORD: No, the report requirements are not related to the material performance. It's really related to the analytical models that are being used to simulate the LOCA. It's a way of, in a sense, controlling changes to the models. If they're discovering small errors, we want to know about them, but we don't need to know about them right away. But if they're finding that they made an error in their calculations that's significant, we want to know about it right away.

CHAIR ARMIJO: Even if it's in a favorable temperature direction?

MR. CLIFFORD: Even if it's in a favorable temperature -- what's favorable?

CHAIR ARMIJO: Well, lower temperature is favorable.

MR. CLIFFORD: But if it was a lower temperature and then they next cycle increased power to take advantage of that, we would want to know about that.

CHAIR ARMIJO: Okay, I'll think about that. I'm just trying -- the purpose of this thing is to see if something is going wrong. That's what I thought that reporting thing -- requirement was, not whether somebody has done something favorable and will later want to take advantage of that, and would come to you with a proposal and say look, we found that peak clad temperatures because of this widget are going to be much, much lower. And we want to take advantage of it for fuel economy, or some other reason. I would think that would be a separate kind of a proposal; whereas, the idea here in this reporting is to spot anything that's going wrong either over time or in let's say one significant change, or finding. But I get the feeling that this is mixed up with a lot of other issues, this requirement.

MR. CLIFFORD: No.

MR. LANDRY: Paul, this is Ralph Landry again, if I can help out.

CHAIR ARMIJO: Yes, Ralph.

MR. LANDRY: The reporting requirement in the rule today has been a very misunderstood requirement, and it has been subject to a number of cases of misinterpretation and misunderstanding over the years.

Because the purpose of the rule is to say that if you have a cumulative change or some absent value, so you can't offset yourself 50 degrees, that indicates that you've made some pretty big differences and big changes in your analytical models. Whether they're errors, or changes in the models, you've made some pretty big changes if you're seeing that much change in temperature, and you have to notify us. You have to let us know that you have a change of this amount. And then you have to tell us what are you going to do, give us a schedule, what are you going to do with regard to this change?

Now, what we've done with adding the oxidation change is said a big part of this rule revision is due to an understanding of oxidation phenomena which are occurring with burnup. That makes the oxidation phenomena as important now as simple temperature has been in the past. So, we want to know if you see a big change in oxidation, relatively big compared to the -- about the same relative sizes with temperature. If you're seeing that much change in your predicted oxidation we want to know that, too. Not just temperature, it's not temperature and oxidation, it's either/or.

CHAIR ARMIJO: Okay. Well --

MR. LANDRY: So, this is to tell us -- this is to make us aware are you making changes that are of a significant magnitude that we need to be aware of them. Otherwise, you report them annually.

CHAIR ARMIJO: Okay.

MR. LANDRY: Everyone has to report annually changes.

CHAIR ARMIJO: Let me give you an example. Let's say you have a best estimate model and your peak clad temperature is 1600 F, and it's got a lot of assumptions even in a best estimate model, and they've done some testing. They found that a lot of those conservatisms were really excessive, and they calculate now that they can -- the real peak clad temperature is now 1600. The time at temperature hasn't been extended so there's no real significant change in ECR. If anything, it's reduced; all favorable. Now, to me that's good news. And why is that reportable?

MR. CLIFFORD: Well, it's --

MR. LANDRY: It's reportable because you've made a significant change. It's not that you've gone to a lower temperature and you were going to do something about it. It's that you've made enough change that we deem is a significant change, and we want to know why we see the significant change. What are you doing that's causing it?

MR. RULAND: The -- actually, we've been looking at this particular reporting section in 50.46 over the past couple of weeks associated with the thermal degradation issue that you might have heard about.

CHAIR ARMIJO: Yes.

MR. RULAND: And we went back and looked at the Statements of Consideration for this particular part of the rule, and the Statements of Consideration speaks to a generalized notion that maybe there's something -- maybe there's a more generalized problem with the way the particular vendor or licensee deals with their models. So, if you see a number of different changes it's an indication to us that maybe there's something we need to look at. So, if there's a whole host of different changes, what's going on and alerts the staff, and we can go out and we can get some information about it, and examine it.

Maybe there's no problem, but it's just a way to alert the staff that some significant changes are going on in the model, and maybe it's something we need to look at.

MR. CLIFFORD: And another way to think about it is, it's a way of controlling the analytical models. They're very large, very complex models and they require extensive NRC review and approval. So, if they were to identify an error and then correct that error on their own and say okay, temperatures went down 300 degrees, we would want to review that model. We will want to be notified that they found a significant change in their algorithms and that it resulted in a significant change in consequences, so we would want to review that. So, they would then have to submit it and let us know. But if it changed by -- if it only changed by 10 degrees then we don't want to be bothered with a formal review if it's only a 10 degrees correction.

CHAIR ARMIJO: But separate from this regulation, you approve these models that they use. Right?

MR. CLIFFORD: They're all NRC approved.

CHAIR ARMIJO: They're all NRC approved, so isn't the change requirement appropriate within that approval process rather than in this regulation? I could see this regulation wanting to trigger notification if there were significant increases in PCT or significant increases in calculated time at temperature which is in the wrong direction from a safety standpoint, but just change because things are changing within a model, it seems to me that's --

MR. CLIFFORD: Right.

CHAIR ARMIJO: -- easily handled within the approval process of analytical models, that you want to keep track of what's going on.

MR. CLIFFORD: I understand. And if you read the section, we define -- we broke it up into several paragraphs, and it kind of follows a logic. The first one is, okay, if you find an error or discover a change then -- discover an error or make a change, and the results are beyond the acceptance criteria, beyond 2200 --

CHAIR ARMIJO: Sure.

MR. CLIFFORD: -- we need action to bring the plant back into compliance, so that's the first variability on this, is that you're beyond your acceptance criteria, your fuel is not going to behave in an acceptable manner, take immediate actions.

The next one is you find a change and the change results either positive or negative, a significant difference than what the NRC last reviewed. And we want to know about it, and we want you to revise your analysis and then submit it to us so we can review it, because we may not agree.

You may say well, it went down 300 degrees, but when we look at it we said oh, no, no, it didn't go down 300 degrees, it only went down 100 degrees. We hadn't reviewed it yet, so we need to be notified of the change, and then there needs to be a schedule for submitting the new analysis.

And then the next potential is that it's only a minor correction. It's a little tiny correction, and in that case we don't need to review the model. We don't need to be notified right away, just on an annual basis they would say we made a correction to the model. It wasn't -- it didn't change significantly either way.

So, the second two which don't involve plant safety are really a way of controlling the approval or maintaining the approval of the model itself.

CHAIR ARMIJO: Well, I can see what you're trying to do, but it just seems like this isn't the regulation in which you should do it. It's in the approval of the models and the maintenance of the models, and things like that. But, you know, let's just go on, because I think I understand.

MR. MIZUNO: This is Geary Mizuno from the Office of General Counsel for the NRC. And I wanted to just address the legal aspect of whether a licensee and, in fact, the fuel vendor is required to report these changes.

Simply as a result of the NRC Staff's approval, as I understand it, these -- the approvals are typically not done by the licensee. They're done on a vendor-specific basis. And the -- in that situation where we're not having a licensing action, okay, one could argue that there is no legal basis for us to impose a -- the kind of approval scheme - sorry - reporting scheme that you're talking about. That is to avoid any legal issue with respect to whether we have the authority to request information regarding these changes, subsequent changes.

The regulation has that reporting scheme directly in it, and it makes no difference ultimately who -- how we approve the model. It puts the licensee in the position of having to report to us.

And, again, I'll just repeat for the

Staff. We're not saying that a change is bad. The reporting requirement is there so that the NRC Staff, in particular, is aware of the change so that they can review it. If they find that there is no problem with it, there is not going to be any further action.

You just have to understand that the reporting requirement is there so that the NRC Staff has the ability to decide whether it needs to look into it further, and based upon their evaluation, inspection, audit, whatever it may be, if additional regulatory action is necessary, then they will take it. That's typically the reason why you have reporting requirements.

CHAIR ARMIJO: Okay, I understand what you're saying, so why don't we just move on.

MEMBER SHACK: Well, I'll just note the current reporting requirement I can see. This certainly clarifies the current reporting requirement where it wouldn't be so clear that a favorable change would have to be reported even if it was significant. So, I mean, that is a substantive difference between the two reporting requirements.

MR. CLIFFORD: Right. And it's not a change, it really is a clarification.

MEMBER SHACK: It's a -- whether it's a

change or a clarification, that's for --

CHAIR ARMIJO: The lawyers --

MEMBER SHACK: -- regulators and lawyers to decide. But it's certainly different.

CHAIR ARMIJO: Yes. Well, you know, I'm going to have to do some more homework on it. When you writing a licensing topical report with an ECCS model and you get it approved by the Staff, I don't know if in the current approvals there are notification requirements of errors or changes.

MR. RULAND: Maybe this will help. When we do a vendor topical report and review it, that is not a licensing action. It is a -- basically, a gentleman's agreement that we have approved this topical report for use, but that's it. It doesn't become a licensing action until a licensee actually submits a license amendment request and then it's incorporated, or there's a technical specification that needs to refer to a particular topical report. So, there's -- a topical report is, like I said, not a licensing action, and I think that probably goes to what --

CHAIR ARMIJO: That makes me even more confused, Bill, but I appreciate it. It's a matter of fact, and I appreciate your telling me that.

MR. RULAND: Okay.

MR. CLIFFORD: Okay, the next Paragraph (m)(iii). This is a new reporting requirement which has been added for measured breakaway oxidation. This cycle-specific reporting requirement is necessary to insure that cladding alloy's susceptibility to breakaway oxidation has not been inadvertently affected due to either planned or unplanned changes in fuel fabrication.

CHAIR ARMIJO: Well, here's another one where I have a big problem; and that is, because this is technical, this is not regulatory language or -- but let's defer that discussion until we talk about the Reg Guides and the findings of your audit.

MR. CLIFFORD: Okay.

CHAIR ARMIJO: Because that's one where I think it's -- my understanding, my experience in working in the fuel business, fuel fabrication, zirconium fabrication, my view is it's an excessive requirement. But let's hold off on that when we get into the technical part of it.

MR. CLIFFORD: Okay. And the last slide is on implementation, and we will be talking about that this afternoon in detail.

CHAIR ARMIJO: Okay. Any questions from

Bill or Joy? Dennis, any questions?

MEMBER BLEY: No, Sam, thank you.

CHAIR ARMIJO: Okay. We're pretty much on schedule. Let's reconvene in 15 minutes at 10:05. We'll take a break right now.

(Whereupon, the proceedings went off the record at 9:51:11 a.m., and went back on the record at 10:06:44 a.m.)

CHAIR ARMIJO: Okay, we're ready for the Staff. Michelle, okay.

(Off the record comments.)

MS. FLANAGAN: Okay. My name is Michelle Flanagan, and I work in the Office of Research in the Division of Systems Analysis. And we were asked to review what the Regulatory Guides were that accompany this rule. We have been before the Subcommittee and the full Committee and got into a lot of details about the Regulatory Guides, how they were constructed, and what the contents were. So, really my presentation today just focuses on how they link to the regulations, and how they enable performance-based language.

And some of this sort has been said already. Rulemaking was initiated to revise the ECCS criteria to reflect new research findings. And we wanted those revisions to enable performance-based features; and, therefore, to satisfy both of these objectives the proposed rule language calls for material-specific analytical limits which account for material-specific burnup effects. And ECCS performance that's consistent with avoiding measured breakaway behavior. And then also the need for periodic testing for breakaway behavior.

So, while the performance-based rule language identifies the high level performance objectives and provides a lot of flexibility we still need to have an acceptable method outlined in order to provide smooth and straightforward implementation of the performance-based rule.

So, we've developed through Regulatory Guides that make it possible to revise 50.46 in a performance-based manner by providing a means of consistent comparable data generation to establish regulatory limits for peak cladding temperature and oxidation, for providing a means of consistent comparable data generation to establish and periodically confirm regulatory limits related to breakaway oxidation, and then a consistent means of using experimental data to establish regulatory limits; basically what kind of margins do you need and how many data points are necessary before you can establish an analytical event.

This also simplifies the Staff's review process, and reduces the regulatory uncertainty of implementing performance-based rule language, and minimizes the cost associated with the implementation.

MEMBER BLEY: Excuse me a minute, this is Dennis Bley. Could you tell me, Michelle, are you on your set of slides? And which one are you on?

MS. FLANAGAN: Yes, sorry. I am on my set of slides, and I'm on Slide 4.

MEMBER BLEY: Okay.

MS. FLANAGAN: And I just completed Slide 4, so I'm about to go to Slide 5.

MEMBER BLEY: Okay, thanks.

MS. FLANAGAN: So, there's three separate regulatory guides that were developed to support this rule. The first one is the test procedure for measuring breakaway oxidation behavior, and then it also -- that test procedure can be used to periodically confirm breakaway behavior.

And then another test procedure is in Draft Guide 1262, and that is for measuring close quench ductility using ring compression tests. And then, finally, the third regulatory guide establishes a way to use the data that's generated in those two test procedures to establish analytical limits.

MEMBER SHACK: Now, are you going to have a new regulatory guide related to long-term cooling?

MS. FLANAGAN: At this point, no. It may — - through the public comment period it may come out that that is necessary or appropriate, but at this time that's not planned.

Okay, so these three --

MEMBER SHACK: Well, just -- what are they supposed to use for guidance then, if you're not going to have one?

MR. CLIFFORD: Well, in the SOC we include a question where we're asking whether or not the basis for the 800 degree temperature that has been used for GSI-191 is appropriate, and whether the data is complete, and whether it could be made publicly available. And if the Staff -- one example would be that we would review that material, find it acceptable for zirconium, and then put that in the rule as an analytical limit.

Another option would be to define a test program. In that case we would then need to develop a reg guide before we went final with the rule.

MS. FLANAGAN: So, the public comment

period for the rule language and the regulatory guides will be at the same time. And the intention of the public comment period is to make sure that the details and expectations that we've outlined in these regulatory guides are communicated effectively and completely.

We also want to make sure that the regulatory guides provide a way that measured behavior can be repeatable within a laboratory, and also repeatable between laboratories. And that analytical limits can be developed consistently across fuel designs.

So, in this -- Paul in his previous presentation presented the rule language, and in this slide I just highlight how it points out to our two regulatory guides for cladding embrittlement. So, the actual language points to the establishment of an analytical limit, and the use of an NRC-approved experimental technique. So, Draft Guide 1263 outlines a method of establishing analytical limits, and Draft Guide 1262 identifies an experimental technique which NRC considers acceptable for informing those analytical limits.

And the same is true for breakaway oxidation. The rule language requires a limit, and that the performance is shown to be not greater than that limit, and that the limit be informed by an acceptable experimental technique. And, again, we have Draft Guide 1263 outlining a method for establishing the limit, and then Draft Guide 1261 identifying an acceptable experimental technique.

So, as I said before, the public comment period for these regulatory guides will be the same as for the rule. And after that public comment period, the reg guides will follow a standard review process.

CHAIR ARMIJO: That comment period is what, 60 days, 90 days?

MS. FLANAGAN: Ninety days, right?

MR. CLIFFORD: Ninety days.

MS. FLANAGAN: Ninety days.

CHAIR ARMIJO: Ninety days. Okay, and then you receive these, and then you take some time to --

MR. LANDRY: Sam, Ralph Landry.

CHAIR ARMIJO: Sure.

MR. LANDRY: The comment period is going to be 75 days.

MS. FLANAGAN: Oh.

CHAIR ARMIJO: Okay.

MR. LANDRY: We're splitting the difference.

CHAIR ARMIJO: Then you consolidate them, evaluate them, and make a disposition, and that's going to take you roughly how long, typically?

MR. CLIFFORD: Well, for the rule I believe we have a schedule that we would have to go final within one year.

CHAIR ARMIJO: Okay.

MR. CLIFFORD: I believe that was what was on Tara's slides. And then the reg guides, then run parallel with the rule.

CHAIR ARMIJO: Yes, okay.

MR. RODACK: This is Tom Rodack from Westinghouse. May I just comment at this point, that this is a tremendous amount of information to review and provide salient comments back on in a 75-day period. I would urge that you consider a longer time for review of these documents. I made this point at previous ACRS Subcommittee meetings on this topic. Just going back to the Advanced Notice of Proposed Rulemaking, and the effort involved in reviewing those documents from experience it will require quite some time on the part of industry to come up with comments on these documents.

MR. CLIFFORD: Do you have a specific time frame that you would like to recommend, 90, 120?

MEMBER SHACK: Ten years.

MR. RODACK: I would recommend 120.

CHAIR ARMIJO: Really?

MR. RODACK: I think there's a lot of information here. Granted we have seen drafts of this previously, but there have been changes to these documents. Well, anyway, for your consideration.

MR. CLIFFORD: Thank you.

MS. FLANAGAN: That was actually my last slide so if -- are there any questions on --

CHAIR ARMIJO: No, we've been through these in detail, unless members --

MR. CLIFFORD: Sam, did you have that question on breakaway oxidation testing?

CHAIR ARMIJO: I think you have a presentation that was more detailed. When you do your talk about your audit -- at least in your draft slides that I received.

MR. CLIFFORD: Right, it gives measured breakaway times.

CHAIR ARMIJO: Yes, and that's where I'd like to bring it up.

MR. CLIFFORD: Okay.

MS. FLANAGAN: Okay.

MR. CLIFFORD: We are way ahead of

schedule.

CHAIR ARMIJO: We're a very efficient committee. But we've done a lot of work reviewing a lot of this in a lot of detail earlier, so unless there's some questions we should just move along. And I have no problem of next on the agenda would be industry. And I propose we just move ahead, if Mr. Eichenberg is ready from TVA.

MR. EICHENBERG: I'll check with everybody to make sure that we've got copies of the --

CHAIR ARMIJO: Yes, they're not separate presentations.

MR. EICHENBERG: Right. We had talked earlier about whether we'd do separate or a combined report, and we finally decided it would be a little bit better for time purposes to have a combined report. We weren't sure whether we were going to be behind schedule at this point or ahead of schedule, or on schedule.

CHAIR ARMIJO: We're very much ahead of schedule, so don't feel rushed. If there's something you want to say, please do it.

MR. EICHENBERG: Now, let me make sure I know which button is the forward button for --

(Off the record comments.)

MR. EICHENBERG: Okay, I'm Tom Eichenberg from TVA, and I'm here representing the BWR Owners' Group. And this is Kurt Flaig of Dominion. He's here representing the PWR Owners' Group.

What we wanted to do was to provide just sort of an overview of what these margin assessment reports are, how they came into being, what their purposes really was, the goals of them. So, we're going to talk about the objectives of the reports, give a little bit of background on how they came into being, talk a little bit about the overall margin assessment process, and then what the conclusions of that process turned out to be.

For our objectives we want to talk about the industry assessments at a relatively high level, and we want to show that the operating plants in the fleet have margin with respect to the research findings.

A little bit of background. As has been discussed earlier and at other meetings, there's been a longstanding amount of research from Argonne National Lab, and that was embodied in NUREG/CR-6967. That really has been the impetus for moving to a rulemaking process which says that the current regs are not adequate.

NRC Staff has requested an assessment of the research results with respect to the operating fleet. This came out of two processes, one was the ANPR process, and another was an internal NRC process to review safety, which ultimately was leading down the path of a Generic Letter.

So, in the course of our meetings with NRC it became clear that a Generic Letter path was going to put a substantial overhead burden on the industry and not really produce the very information that the NRC needed.

So, what NRC did was we proposed to provide separate reports on a voluntary basis, and the benefit of this would be that it would reduce the overhead burden, but it would also give NRC the information they wanted on a faster schedule. And in order to coordinate all of these things, the process was coordinated through NEI.

CHAIR ARMIJO: Well, I'd like to compliment the Staff and the industry for finding a very practical way to skin this cat, because it needed to be done.

MR. EICHENBERG: Yes.

CHAIR ARMIJO: And this was the right way to do it, rather than the ponderous regulatory Generic

Letter process.

MR. EICHENBERG: Right. And we felt it was important to have a central point of contact, so we established NEI as that central point of contact simply because there are what I'll call overlapping interests amongst the various groups in the industry. So, with NEI being able to coordinate things it was easier to assign responsibilities and get the process moving.

We want to talk shortly about the assessment itself. We want to talk about the approach to what we call the initial survey. It's kind of really talking about the starting point, where do you start this whole analysis from.

We wanted to go through some mechanism to identify what are the criteria we're going to measure against, because as we all know, there is no rule in place. So, we're sort of going as we take each step.

One of the goals was to identify in current methodologies what are the conservatisms that we know of, and what are those conservatisms worth, and how can they help us to establish that we really do have margin to these research limits even though a specific licensing methodology was never intended to compute that type of margin.

And then we also want to explain a little bit about the plant grouping approach that we took, and why plants have been kind of lumped into groups rather than just going through each individual single plant.

So, with respect to the survey, the starting point was a bit difficult to try to figure out how could we get all the plants to be at the same place at the same time and have some sense of it all. And in the end, we came down to saying each plant at some point had to have a full-blown analysis of record, which loosely translates into a break spectrum analysis. So, that was one point where all the vendors could say every single licensee has been analyzed. So, we chose that as the starting point.

Now, there was some confusion because some people consider their analysis of record to be the actual 50.46 annual reporting rack-ups, but not everybody treats it that way because the rack-ups themselves are not a full-blown break spectrum analysis, so we chose just to start at a more common point that everybody could basically fulfill.

And then in looking at the individual licensees and trying to establish what is their initial margin; so, for example, everybody or I shouldn't say everybody, some plants maybe they have an Appendix K-based analysis, very conservative, and it is using oxidation mechanisms primarily through the Baker-Just correlation. So, you might say let's look at every plant and see what their Baker-Just oxidation is, and maybe we'll get lucky, and some of them will already meet the existing criteria, and we can effectively say that there is no need to take any kind of credit whatsoever. But there are going to be places where some amount of conservatisms and credits would have to be determined, and then we would have to take those into account as we process each and every licensee.

So, I'll turn it over here to Kurt.

MR. FLAIG: Thank you, Tom. Good morning.

I'm just going to take you through the next few slides here. We're going to talk a little bit about the evaluation basis. Basically, the ground rules for the two groups to perform the analysis, talk a little bit about the embrittlement limit. This is an NRC proposed limit that was used here, 18 percent at zero ppm, the break point at 6 percent at 400 ppm, and then down to 4 percent at 600 ppm.

The PWR Owners' Group modified that slightly and presented that to the NRC in their assessment report. And we'll look at that in a slide down the way here.

Obviously, the embrittlement limit is based on hydrogen uptake models that need to be approved by the NRC. And they are alloy-specific models then, and each one of those models was provided in our assessment report.

We need to understand how to deal with double-sided ECR. The evaluation models typically handle double-sided corrosion at burst limiting locations but away from burst limiting locations we needed to account for the oxygen ingress, so that was done.

We also had a criteria for breakaway oxidation. We've talked about that earlier today, 800 degrees is what was used in the assessment reports.

This is the embrittlement criteria that was used by the PWR Owners' Group. It is only slightly different from the values that I indicated before. We reduced the zero ppm number down to 17 percent, and we extended the curve out to 800 ppm.

CHAIR ARMIJO: But the break point at 400 ppm and 6 percent ECR is the same as the --

MR. FLAIG: Yes, this break point is the same.

CHAIR ARMIJO: Yes.

MR. FLAIG: That break point is the same.

CHAIR ARMIJO: So you just extended it beyond -- what did the Staff --

MR. EICHENBERG: Well, one of the problems with the original proposed limit as it was in the GL proposal was that it just kind of stopped at 600, and there was no step change, there was no nothing. It just kind of said stop. So, we said we need to have some sort of meaningful continuous line that will cover us should we happen to get out to such ppm numbers.

CHAIR ARMIJO: So you dropped the --

MR. EICHENBERG: So, we just chose to linearly extend what was there.

CHAIR ARMIJO: Okay.

MR. EICHENBERG: Now, I believe that we in the end turned out we didn't need to take any advantage of that really high ppm values. I'm not entirely sure of that. We have some of the vendors' representatives here who could probably speak specifically to that.

CHAIR ARMIJO: If I recall there was never test data out at those --

MR. EICHENBERG: I think 600 is where the highest test data --

CHAIR ARMIJO: Yes, so that was just a pure extrapolation.

MR. EICHENBERG: Just a pure extrapolation to say we have a continuous curve.

CHAIR ARMIJO: Okay, we'll talk about that later.

MR. FLAIG: Okay. We need a hydrogen-uptake model to apply for each alloy, and here's an example of the one for Zircaloy-4 that is in the public forum, fairly straightforward here. Lower values at lower burnups going up to higher values at higher burnups.

For double-sided ECR contribution it was applied at rod exposures above 45 kilowatt-days per metric ton, something that we discussed in front of —- - at public meetings back in December 2010.

CHAIR ARMIJO: Could you step back to that previous chart? Do you have -- just for the convenience, do you have a chart on that same scale for all the current alloys in use in the U.S. fleet?

MR. FLAIG: I have in the assessment report for the PWR Owners' Group there is plots, and I have them with me on some backup slides for both ZIRLO and -- ZIRLO-1 is proprietary and it's just an example. We have an M5 one, as well, and I believe there is some information for the BWR Owners' Group.

MR. EICHENBERG: Yes, the BWR has a ZIRC-2 type curve on it. Right?

CHAIR ARMIJO: And the -- well, if we want to see the proprietary stuff we have ways of closing the meeting and discussing that if we need to.

MR. EICHENBERG: Right.

CHAIR ARMIJO: But at some point it would be nice to have all of these curves on one chart so we have an idea where we are.

MR. EICHENBERG: Yes, a consolidated chart could prove interesting just in terms of clarifying the whole situation.

CHAIR ARMIJO: Yes.

MR. FLAIG: Okay, we'll move forward here. I talked about double-sided ECR contribution. Breakaway oxidation, we applied 5,000 seconds above 800 degrees as a basis based on some ANL testing and industry testing.

CHAIR ARMIJO: And where did the 45 gigawatt days per ton come from? Why is that a --

MR. EICHENBERG: My understanding of 45 gigawatt days is that that is the proposed value in the Draft Reg Guide.

CHAIR ARMIJO: I remember seeing something like 50, maybe I'm --

MR. CLIFFORD: The value -- it's really when you start having a fuel cladding bond layer to the extent to which you have that bond layer. And it would be fuel design-dependent, and it would also be dependent on operating history. We felt for the purpose of this exercise, 45 was a reasonable threshold to start consider this oxygen in the cladding.

In the regulation, the proposed regulation it would be up to the licensee for his specific fuel design to provide evidence of when that oxygen --

(Coughing.)

MR. CLIFFORD: So it could vary from 40 to 50. It's going to be somewhere around 45 based on what we know today.

CHAIR ARMIJO: Okay. So, if particular fuel manufacturer has data, hot-cell data or something that shows he's got little or no fuel clad bonding at 45 or 50, he could actually propose a different value at which he applies that.

MR. CLIFFORD: Absolutely.

CHAIR ARMIJO: Okay. And conversely, if he's got a particular situation where he's seeing that in significant amount of bonding at lower burnups that's his job to show you?

MR. CLIFFORD: Yes.

CHAIR ARMIJO: Or does that 45 protect him?

MS. FLANAGAN: The Regulatory Guide provides an option if no data is available or if it's just not productive to collect data, the Regulatory Guide provides an option that you can just say 45 as a limit that can be supported without any other data. It's like a default.

CHAIR ARMIJO: And is the extent of fuel clad bonding, in your mind are you thinking in terms of half the ID surface, 10 percent of the ID surface has got fuel bonded to the cladding? Do you have a position on that of what --

MS. FLANAGAN: We wanted to select a value that was low enough that we knew that the bond - sorry - the hard contact existed, but then it isn't necessarily true that that will be sufficient for diffusion of oxygen. It's just that we think it's conservative. And then a vendor would have to supply information that says how much hard contact plus an actual bonding layer would be required until you actually get diffusion of oxygen during that transient. And that may be a different burnup.

CHAIR ARMIJO: Okay. Well, hard contact by itself isn't a guarantee you have fuel clad bonding. It's time, temperature, burnup, a whole bunch of things, and unless you have hot-cell data where you can actually see the extent of bonding you're kind of guessing. And I just wanted to know if the Staff is expecting -- and I guess you answered my question. You don't expect -- you would not request any data below 45. And if somebody wanted to propose that they don't need to account for double-sided oxidation up to 50 or 60 they have to show you a pretty convincing set of data.

MS. FLANAGAN: Right.

CHAIR ARMIJO: Okay, I understand.

MR. FLAIG: Okay. The next slide is an example of some of the applied conservatisms that were used during the evaluation of the individual plants. The obvious ones are Appendix K versus Best Estimate methodology. There are many plants out there that still have Appendix K methods, so moving to Best Estimate methodology is a conservatism that can be applied and used to improve the outcomes.

Another one is approved Best Estimate methodology improvements; basically moving from one approved Best Estimate method to another. The use of Cathcart-Pawl in place of Baker-Just. We also looked at reload power histories. We looked at peak cladding temperature-dependent brittle fracture transition. Essentially, a reduction in PCT will provide an increase in ECR.

We looked at using the ANS-1979 decay heat standard plus two-sigma uncertainty, and then another example would be thermal mechanical limits to operation, linear heat generation limit, that was applied.

So, these were just some examples of conservatisms that are laying out there for us to look at in the process of going through the assessment. These are ones that are not unapproved type of conservatisms, but those that have been used by the industry in various places.

Talk a little bit about the plant grouping factors. We talked when we were here before about grouping them with regards to plant design and ECCS features, but we also considered things of large versus small break being limited. We considered the type of cladding material. We considered what type of evaluation model, and whether or not to group according to that because you would apply different conservatisms potentially for those types, so, to group that way was considered. So, the types of conservatism credits were considered then in how we wanted to group the plants so that they would be best able to present in the assessment what the results were. So, we just have on the next few pages here some basic summary information about the grouping that was done.

For the PWR large-break, and for PWR we had seven groups for the large breaks, and we have three separate groups for the small breaks. You see before you the group 1-4. For Group 1 which contains 41 units, the majority, no adjustments were required to meet the limits. For Group 2, just two units in there. We needed to --

CHAIR ARMIJO: These were all Appendix K?

MR. FLAIG: No, sir.

CHAIR ARMIJO: The Group 1 were not?

MR. FLAIG: Group 1 was a combination.

CHAIR ARMIJO: A combination.

MR. EICHENBERG: Group 1 for the --

MR. FLAIG: I'll step back for a second. For the PWR Owners' Group we very much decided to look at the type and number of adjustments required in order to show that we met the limits, so the groups are on that basis; the types of adjustments necessary to show that we meet the limit. So, each individual group may contain more than one type of methodology, one type of plant design, more than one type of ECCS design. So, with regards to the adjustments, none were needed for Group 1, and that's the basis for the grouping there, is that no adjustments were necessary to meet the limits.

CHAIR ARMIJO: Including Baker-Just --

MR. FLAIG: Nothing at all.

CHAIR ARMIJO: Okay.

MR. FLAIG: Okay? For Group 2 we looked at approved Best Estimate methodology improvements to show that those met the limits, and the calculated ECR was reduced by approximately 50 percent by using those improvements.

For Group 3 which contains six units, the conservatism applied there was Appendix K. Moving to a Best Estimate methodology provided us a calculated ECR reduction of approximately 60 percent.

Group 4 contains four. We looked at improved statistics in the ASTRUM methodology, reducing a calculated ECR by approximately 40 percent.

And then for the last three here, for Group 5 we looked at an explicit burnup study reducing ECR by 50 percent. Group 6 we looked at -- Group 6 and 7 we have multiple conservatisms that are used.

For Group 6 the approved Best Estimate methodology improvements, as well as improved ASTRUM statistics improved our ECR calculated value by 60 percent. We also increased the allowable ECR criteria by looking at the reduction in PCT.

For Group 7, eight units in that group. We looked at moving to Cathart-Pawl as well as reload power histories, and we reduced the calculated ECR by 40 percent. So, you can see that the conservatisms are rather large that we looked at for the large-break LOCAs.

For small-break we just have three groups. Again, Group 1 contained 59, and this is the group that there are no adjustments required for to meet the limits. For Group 2, contained five units, and we applied the ANS-1979 decay heat standard plus two-sigma uncertainty. That's something that is typically applied in Best Estimate methodologies, and the ECR was reduced by 90 percent, so significant change there.

And then for Group 3, the last group here contains five units. And we looked at moving to Cathart-Pawl, as well as reload power histories and reduced the ECR by 30 percent.

CHAIR ARMIJO: I'm curious why you didn't use the reload power histories more.

MR. FLAIG: More?

CHAIR ARMIJO: Generally, you know, you have all this.

MR. FLAIG: They are available. They are plant-specific values, but we didn't want to use everything in the bag necessarily. Okay? We used what was easiest to grab. Obviously, moving from Appendix K to Best Estimate models was an easy thing to look at. Looking at -- in this case, this slide here looking at ANS-1979 decay heat plus two-sigma uncertainty was an easy adjustment to grab. So, there wasn't a need to look at reload power histories for all the different groups, so if it wasn't required we didn't apply it.

MR. EICHENBERG: Maybe one more way to think about this is that for these groups there may be only be one or two, in some cases three credits that were taken in order to show that there's positive margin to the proposed limit, but that's not to say that we went through every single possible conservatism that's out there. So, there's still a lot of conservatism sitting out there that has not been credited. And, ultimately, as the process evolves and we get to new methods that are reviewed and approved by NRC, we'll step through all these conservatisms and come to some agreement about what is the proper amount of conservatism to keep in the basis. But we're really just trying to show that it doesn't take a lot in order to meet the margin. So, that pretty much covers the breakdown of the PWR groups.

The BWR groups, in coming up with these groupings --

MEMBER SHACK: Well, just let me --

MR. FLAIG: Sure.

MEMBER SHACK: The way you've done it, that means I really shouldn't put too much stake in any margin that you found. You just sort of got credit until you met the goal, sort of like a CUF in analysis, if you get below one, you quit.

MR. EICHENBERG: Yes. The purpose was simply to --

MEMBER SHACK: To get what's necessary to say that there is margin. Okay. So, the --

MR. EICHENBERG: As opposed to a full-blown licensing calculation which essentially can't be done because there's no approved method.

CHAIR ARMIJO: Let's take just a hypothetical. You take one of these plants and you pull out all the stops. You use all of your, I won't call them approved margins but certainly --

MR. EICHENBERG: Rational margins.

CHAIR ARMIJO: Yes. Are we talking about reductions in ECR over 100 percent, not 100 --

(Simultaneous speech.)

CHAIR ARMIJO: How big of a --

MR. EICHENBERG: Maybe one thing to keep in mind is that these reductions are -- they are the relative percent change from that starting point. So, as soon as you start to mix apples and oranges together, it's affecting PCT -- it's affecting your temperature profiles, and it's affecting, obviously, then your oxidation rates in very different manners. So, it's not real easy to compare the end state to the beginning state.

CHAIR ARMIJO: Unless you do a full analysis.

MR. EICHENBERG: Unless you do the full-blown thing. So, while some of these reductions, particularly in the case of the decay heat curve being 90 percent reduction, we just need to remember that the reason it's 90 percent is because the starting point was so big compared to where just this one credit got you.

CHAIR ARMIJO: Okay.

MEMBER SHACK: But when I see, for example, a grouping with plants it looked to me like pretty similar beasts, and yet the margins --

CHAIR ARMIJO: Vary.

MEMBER SHACK: -- vary markedly. That's just an accident perhaps of the --

MR. EICHENBERG: And it's the result of choosing the binning structure in this manner based on credits. And what we'll see when we look at the boiler stuff is that those bin structures were not necessarily based on credits. They were more based on -- it was easier to say break them up by design.

MR. CLIFFORD: Yes, and if I could say something. If you had two identical plants, if one was using Appendix K and the other one was using Best Estimate, there would be an enormous difference in initial margin. And, also, if one was using say M5 and one was Zirc-4, there would be an initial heat difference in initial margin, even though they both had the same --

MEMBER SHACK: What I was looking at was the final margin after they took all the credits. I looked at a group of plants it seemed to me relatively similar, same design, roughly same power, same cladding. And yet when I get down to the margin that's left, it can be quite dramatically different in some cases.

MR. EICHENBERG: Right, because each bin has just got a homogenized group of plants in it.

CHAIR ARMIJO: Okay.

MR. EICHENBERG: On the BWR side, the groupings were -- it just turned out to be easier to do it by plant design. So, there was no Group 1 because we don't have any BWR-1s to evaluate, so we just jumped right to Group 2. So, we started out with Group 2 designs which are the BWR-2s, the non-jet pump plants. And in that context we took credit for the conversion from Baker-Just to Cathart-Pawl. And then we took credit for what we call the thermal mechanical operating limit. And what that essentially says is that at no point during operation can you be running at an LHGR limit above what your COLR says you're allowed to run at. And just the simple act of saying that's how much power density I have limits how far the PCT can go. And there's a meaningful benefit to that.

So, for the BWR-2s we just took a couple of simple credits and we were able to reduce the ECR by about 20 percent from the starting point. And that was sufficient to show margin to the proposed rule.

In the case of BWR-3s it was even more simple, yet we only really needed to take credit for the fact that LHGR limit existed. And just in doing that we got about a 95 percent reduction in ECR relative to the starting point.

But for the vast majority of boilers, all the BWR-4, 5, and 6 designs, there was no requirement for any adjustments, that you were able to meet it with the current licensing methods. So, in that respect the BWR groupings were actually a much more simple matter than the PWR.

CHAIR ARMIJO: Okay.

MR. EICHENBERG: So, to kind of summarize what the margin was showing was that for embrittlement purposes 41 of 69, which was roughly two-thirds of the fleet in large-break space required no adjustment. And some were upwards of 80 percent or so, and the PWR small-break required no adjustments whatsoever to meet the current margins. And almost all the boilers were in the same situation, no real adjustments or credits were required.

And then in the case of all the remaining plants, as we discussed, various credits were taken but we didn't take any sort of wild conceptual credits, and we certainly tried not to take advantage of any kind of a plant-specific I'll call them design type things that change from cycle to cycle.

Now, in the case of the boilers this thermal mechanical limit, one could argue that that has the potential to change from cycle to cycle, but in reality those limits are pretty much fixed, and they very rarely change. Every cycle is pretty much the same. Every plant uses the same thermal mechanical limit, and it's pretty much a non-changing entity.

In terms of breakaway oxidation what we found was that all the plants were able to meet the 5,000 second margin without any credit.

CHAIR ARMIJO: And that's Bs and Ps.

MR. EICHENBERG: Bs and Ps.

CHAIR ARMIJO: So, this even applies to --

MR. EICHENBERG: Just as blanket. And then, basically, as a result all the operating plants we were able to show margin with respect to the research findings.

CHAIR ARMIJO: Okay.

MR. EICHENBERG: And then concluding, we just wanted to state that the industry was able to provide the margin assessment reports that encompass the entire operating fleet, and that all the operating plants showed margin with respect to the research findings.

CHAIR ARMIJO: So, if you just go a couple of steps, when this rule comes out, assuming there's not radical changes, the actual implementation and compliance with the rule should be pretty straightforward. Some work to do, but if you guys have concerns, this is a good time to raise them.

MR. FLAIG: Well, I think that these assessments show that for the criteria considered there is margins there and that we can achieve that success. I think it's the process that we need to go through in terms of what methodology changes have to be made to various evaluation models, what's the approval through that evaluation model review and approval practice? What do licensees need to do to then pick that up, work the vendors to get that work accomplished, submit it to the NRC. What type of additional licensing actions are required through text spec changes or COLR reference list changes that need to be made to put all of this in place.

It seems rather simple and straightforward to look at the plants that have really no adjustments required, but there's a fair amount of work that has to go into meeting the rule language as we've heard it this morning in terms of demonstrating that the methods that the vendors have are sufficient to meet that rule language, and to then have all the licensees put that information in a place where it needs to be.

Many licensees have listed in their COLRs the approved LOCA methodology approved by the NRC as a basis for their peaking factors. So, this would be what I would think would be an update to that information in the COLR, and that's not a simple process as you know it in the NRC. And it's not a simple process as the licensees know it.

So, you asked me do I have a concern? I think the industry has a concern of the length of time, the resources necessary both at the licensees and at the vendors, and at the NRC to accomplish this effort in a timely manner without doing something up and above --

CHAIR ARMIJO: Well, let me put my question a different way. If you've got 68 plants, BWRs and PWRs combined that you say needed no adjustment to show margin, and using approved --

MR. EICHENBERG: Using the existent --

CHAIR ARMIJO: -- existing approved methods -- and yes, I know there's always implementation work that has to be done, but if that was the only problem -- if that was the only set of plants you had to deal with, why isn't this pretty straightforward? I mean, nothing changes.

MR. EICHENBERG: In some sense it's straightforward, but in other senses it's not. Typically, if you were to have a methodology change as a licensee you're going to have to have an approved method, and then you're going to have to put in a license amendment request citing that you want to have that new method as part of your text spec references. And then has to get approved so that you can then do that and update your FSAR.

In the process of doing that, you're really complying with two different things. One is, I'm complying with the new rule. The other is, I have to comply with my text spec as written at any given instant in time. So, that entire process that I just described is really trying to get you through both compliance phases.

One of the problems that the industry has in digesting this is what is going to be the definition of compliance demonstration. And hypothetically just reading the language that I've seen, you've got a situation where you could say well, maybe the first group of plants which has a 24-month block of time, we're going to give some special allowance for what the definition of compliance demonstration is.

Okay, maybe that doesn't mean I have to go all the way through a text spec submittal and all these other things. What happens to those licensees on day 24 months plus a day, because all you've done is answered the I complied with the rule part. You still haven't addressed the how do I comply with making my tech specs work, because I'm still required to comply on a daily basis with the way my tech specs are written.

So, there's two pieces to the puzzle, and we really need to figure out how we're going to conquer both pieces of that puzzle and not let them get so disjointed that we create I'll say a tank trap to fall into, and that nobody can get out of.

So, we haven't had a lot of time to look at the language. Plus one important piece that we haven't had any chance to see is what will the Statements of Consideration be. So, until the rule is published as a draft, we're not really going to have any access to that. We need to understand that first before we can come up with real specific comments.

So, we have some concerns, but we think they're the kinds of things that can be worked out. Just speaking from my personal preference, I would prefer not to have literal licensee names in the rule. I'd prefer to do something that was more along the lines of what NRC has done in other rulemaking situations where the licensees provided a plan within say 60 or 90 days of how they intend to comply. And then you've got a situation where NRC Staff and licensees can sit down and come up with an orderly schedule of who needs to go first, helps you to understand which methodologies need to get into the pipeline first, because we really have, for lack of a better term, a resource issue with how quickly can we process methodology reviews, how quickly can we process tech spec license amendment reviews, and how much of that can be done in parallel.

And, ultimately, that's going to drive how you get to some sort of schedule date. So, we're really going to need to see not only the rule language as proposed, but the Statements of Consideration so that we can go through and develop some kind of -- the industry will develop some sort of alternative. And we'd really like to have the opportunity to sit down with Staff and have a public workshop to talk about how we best get to that best place.

MR. LANDRY: This is Ralph Landry from NRO. You've already seen the exact rule language so far, and as you said, you haven't seen the SOC. We have a lot of questions in the SOC that we're asking for specific feedback on. And this is one of those areas. So, we're going to be giving you the opportunity to give us feedback and figure out what is the best approach for the implementation of the rule.

CHAIR ARMIJO: You know, just being real simplistic, assuming that everything you found is accurate and correct, and you're in de facto compliance right now, is that wrong?

MR. EICHENBERG: The bulk of the plants with the existing license methods could make a statement that they meet proposed rule language based on what we right now would have to say are assumed hydrogen uptake performance models. And that's one issue that I don't think has been addressed at all, is how are we going to define an acceptable hydrogen uptake model? There's no reg guidance on that. It's not really discussed in the rule itself, and it's hard to step -- take that first step to say I'm in compliance when we don't have anything that says what constitutes compliance for hydrogen uptake.

CHAIR ARMIJO: I thought we had models or data that have been approved.

MR. EICHENBERG: Well, we have -- the vendors have some data, but that's not the same thing as saying that we have methodologies that have topical reports submitted that have SERs associated with.

MR. CLIFFORD: This is Paul Clifford. We have reviewed hydrogen uptake data, and we have used that data to make regulatory decisions. For example, there's a SAFDL on cladding strength, during an AOO you get an overpower transient, how much strain can your cladding -- how much strain in the cladding go before it fails? And say there's 1 percent as a number, well, that's dependent on how much hydrogen is in the cladding. If there's a lot of hydrogen maybe you're not able to achieve 1 percent.

So, we have reviewed data for regulatory purposes, but we haven't reviewed data to establish what --

CHAIR ARMIJO: But assuming that you had a set of data for one particular type of cladding that was acceptable in that review, wouldn't it be reasonable that -- to find that same set of data acceptable for this application?

MR. CLIFFORD: I believe there's data out there. I believe --

CHAIR ARMIJO: Okay.

MR. EICHENBERG: There is certainly the potential for that. And one of the issues that would not yet be settled is, does hydrogen uptake need to be upper bound toleranced, or does it need to -- or is it okay just to be a best estimate mechanism?

MR. CLIFFORD: Yes, that level of detail is what needs to be worked out. Whether you have a peak nodal average, whether it's a circumferential average, or a peak, or --

MR. EICHENBERG: There are more technical issues of how you define acceptable, but we can clearly, I think, get to acceptable, but it's going to take some time to get there.

CHAIR ARMIJO: Okay. And those kinds of issues you'll raise, or somebody is going to raise in the --

MR. EICHENBERG: Yes, we will certainly bring those issues up during the draft comment period.

CHAIR ARMIJO: Okay.

MR. FLAIG: The other thing I guess I'd like to note since we're talking freely here a little bit, and you mentioned it, too, which is the long-term core cooling and its relationship to GSI-191, and even trying to come to an establishment of a limit for that embrittlement, it's kind of sitting out there very bare bones at this point in time. And to say that we meet that limit, there's no limit, there's no reg guide, there's no structure to that at this point in time. So, I'm personally left in a quandary of where am I going to go here.

CHAIR ARMIJO: Okay.

MR. LANDRY: This is Ralph Landry again. That's one of the things that we want to get feedback on. As I said earlier this morning, we tried to take something that has no definition virtually and put some definition to it in a performance-based manner so that it's not just picking an arbitrary number, an arbitrary statement of how you meet it. We're trying to make it performance-based so that you tell us how you meet it. But we're -- this is one of those areas that we're waiting for feedback on. We can't guess at everything.

MR. EICHENBERG: Obviously, we're at this stage of the process.

MR. LANDRY: We're trying to take uncertainty out of the process.

MR. EICHENBERG: We're not quite at bring me a rock part of the process, but we're still not fully away from it.

CHAIR ARMIJO: I think that particular one sounds little bit -- but I'm sure you can work it out.

MR. EICHENBERG: Okay. That's what we had for slides.

CHAIR ARMIJO: Okay. Any questions? Bill, Joy? I think that's very helpful, and we did get your material. We've been looking at it.

MR. EICHENBERG: Okay.

CHAIR ARMIJO: So, I think that's all we've got, so we're moving right along.

MR. EICHENBERG: Right along.

CHAIR ARMIJO: That's all I can tell you.

MR. BROWN: Sam, don't forget Dennis is on the phone.

CHAIR ARMIJO: Dennis, I'm sorry, did you have any comments or questions?

MEMBER BLEY: Sam, thank you. Not really. I was a little uncomfortable, I guess, seeing all the different criteria apply to different plants, but given the purpose of the analysis I think that's fine. And I got a better picture of what some of the problems might be on implementation, but I don't have any further questions. Thank you.

CHAIR ARMIJO: Okay. All right. Well, it's

11:00 and we're way ahead of schedule, and I think we should just keep moving, and there's no law against finishing early.

MEMBER SHACK: Just a quick question. Is there -- I was trying to figure out whether there was some rationale for the way the implementation dates were picked, and I couldn't come up with --

MR. CLIFFORD: We'll discuss that in the next one.

MEMBER SHACK: Okay.

(Off the record comments.)

MR. CLIFFORD: Okay. When research yields new information which brings into question existing regulatory requirements, the Staff must address the following questions. First, are the research findings credible? Second, is it complete? Third, is there an imminent risk to public health and safety? The answers to these three questions inform the decision on how quickly new requirements are developed and enforced throughout the community or the industry. The next two presentations will address these three items and the Staff's recommendation on implementing new requirements.

As some quick background we will touch upon the research findings, and then we will go into

Staff's initial safety assessment followed by the Generic Letter, and then the Staff's ECCS performance assessment which builds upon the BWR and PWR Owners' Group reports.

The first new embrittlement mechanism identified by the Argonne Research Program was hydrogen-enhanced beta-layer embrittlement. Essentially, the pre-transient cladding hydrogen which occurs as a result of water site corrosion during normal operation has a direct impact on the rate of embrittlement.

This figure here shows measured ductility or deflection on samples that were fresh Zirc-4 and high-burnup Zirc-4. You could see a clear shift in the measured ductility as a function of CP ECR.

As a result of this new embrittlement mechanism the allowable time at temperature to reach nil ductility decreases, and this is clearly shown on this plot. All of this information has been presented prior to the ACRS.

CHAIR ARMIJO: Sure. That is the ring compression test strain?

MR. CLIFFORD: Correct.

CHAIR ARMIJO: Okay.

MR. CLIFFORD: Well, actually, this would be the ring compression test.

CHAIR ARMIJO: Yes, that one.

MR. CLIFFORD: And this would be the threshold.

CHAIR ARMIJO: Right.

MR. CLIFFORD: You achieve 1 percent.

CHAIR ARMIJO: That's what I meant.

MR. CLIFFORD: The second embrittlement mechanism is that oxidation which may be present on a cladding ID can diffuse into the base metal, and increase the rate of embrittlement. And whether or not there is an oxygen source which is directly related to a fuel clad bonding sensitive to burnup, power history, and fuel rod design.

These figures just illustrate that an alpha layer -- oxygen-stabilized alpha layer occurred during testing both on the ID and the OD of high-burnup fuel rod segments.

The third embrittlement mechanism identified by research was a phenomenon we refer to as breakaway oxidation. Essentially, there's a shift in the structure of the oxide layer which causes it to become unstable, and as a result it degrades and gross amounts of hydrogen are taken up and it becomes brittle due to hydrogen uptake.

We believe that the sensitivity of a particular alloy to the timing at which breakaway occurs, it would be sensitive to alloy composition and fabrication.

MEMBER SHACK: We always show the worst-case picture.

MR. CLIFFORD: Yes.

CHAIR ARMIJO: Yes, I think that's -- I won't use the term "yellow journalism" but it's close.

MR. CLIFFORD: Remember the first question was is the research credible? Well, the answer is yes. NUREG-CR-6967 documents the research data. The findings have been presented to this Subcommittee, and I think everyone in this room believes that the new embrittlement mechanisms are real and well supported.

The second question is, is the research complete? The research conducted at Argonne included testing on unirradiated hydrogen-charged and irradiated fuel rod cladding segments, and included many different zirconium alloy compositions.

The Staff did identify some small gaps which needed to be filled to enhance this already extensive empirical database to support the rulemaking, and these are identified here on this slide. And they were that there needed to be a few additional tests at intermediate hydrogen levels, there needed to be some breakaway oxidation tests performed on transient temperature profiles, and there needed to be a more robust technical basis for the treatment inside the fuel rod burst region.

All this research has been completed. This research has been presented to the ACRS Subcommittee, and RIL-0801 is being supplemented to capture all of the research that's been done since the original July 2008 RIL-0801.

The third question was is there an imminent risk to public safety? In response to RIL-0801 NRR completed an initial assessment which its purpose was to determine what course of action do we take. Should we say oh, there's a problem, we need to issue orders, we need to issue bulletins, we can forward with rulemaking. So, you need to identify first whether there's an immediate risk.

Well, based upon the measured cladding performance from Argonne, crediting realistic rod power histories and some current analytical conservatisms in July 2008 we determined that there was no imminent safety risk, and that the best course of action was to proceed with rulemaking.

Recognizing that the finalization and

implementation of the new requirements would take several years, the Staff decided that a more detailed plant-specific safety assessment was necessary. To obtain the necessary information, we developed a draft Generic Letter, and held several public workshops. And during those public workshops the industry volunteered to provide all the data that the NRC was seeking using an alternative means. And that was the BWR/PWR Owners' Group reports which was previously presented.

In addition to reviewing the Owners' Group the Staff conducted audits of the Westinghouse, AREVA, and GE engineering calculations, and based upon those audits, the information collected during those audits and the Owners' Group reports we concluded that there was sufficient plant-specific information to complete our safety assessment. And, therefore, no further regulatory action was necessary, and the draft Generic Letter need not be issued.

The next section we'll discuss how we use the information that became available as a result of the effort from the PWR/BWR Owners' Group to confirm individual plant safety.

These ground rules were previously discussed, so I won't go back into them except for this plot. Dr. Armijo, you mentioned that you wanted to see a plot where all the alloys are presented. Here's kind of an illustration of the alloy dependency of hydrogen pickup. If you convert the same -- if you convert this curve using alloy-specific hydrogen content convert from hydrogen to burnup you end up with something that looks like this.

CHAIR ARMIJO: Yes. Now, in the case of the ZIRLO is that the -- is optimized ZIRLO any different than plain original ZIRLO?

MR. CLIFFORD: Yes, the oxidation can significantly improve with optimized ZIRLO.

CHAIR ARMIJO: Okay.

MR. CLIFFORD: Hence, the name.

CHAIR ARMIJO: And it was optimized for hydrogen pickup. Was that basically the --

MR. CLIFFORD: The pickup fraction was approximately the same, so it would have a lower oxidation, and at the same pickup fraction less hydrogen.

CHAIR ARMIJO: Okay. But we don't have that on that curve there. Is that proprietary? Is that a reason for that?

MR. CLIFFORD: Yes.

CHAIR ARMIJO: Okay. But in time the

ZIRCALOY-4 will disappear from the fleet, and even the old ZIRLO I would assume disappear, and optimized ZIRLO would become their standard?

MR. CLIFFORD: I believe right now there are only four plants that currently load fresh fuel with ZIRC-4. And I believe they have plants -- I've been informed that they have plans to migrate to some advanced alloy. I can't speak -- Tom Rodack is sitting behind you. Maybe he can speak to whether or not the industry is moving off of ZIRLO to optimized ZIRLO.

CHAIR ARMIJO: Yes.

MR. CLIFFORD: A handful of plants, but we don't know the intent of the remaining fleet.

CHAIR ARMIJO: Okay. And in the pipeline there would be new alloys. We know they're in development, but they would have to comply with these regulations and go through the testing to make sure they were consistent.

MR. CLIFFORD: Absolutely.

CHAIR ARMIJO: Okay.

MR. CLIFFORD: Absolutely. Okay, a brief survey of the available data that's in the plant FSARs, here's a plot. The number of plants on the Y axis and then you have calculated local oxidation.

These may be a little -- what I did here was took the maximum local oxidation from either the small break or the large break. So, as you can see there are approximately 40 plants that are calculated less than 3 percent ECR. And the numbers drops to about 25 between three and six, roughly 15 percent between six and nine, and nine and twelve, and greater than twelve. So, this just gives you a feel for how close they were to the research data had they taken no credit.

Here's a similar plot, number of plants versus the calculated time above 800 C. As you can see, a majority of the plants are less than 500 seconds. There's roughly 30 plants between 500 and 1,000, 10 plants between 1,000 and 2,000, and there's one single unit greater than 2,000.

Post quench ductility. The revised post quench ductility analytical limits. There may be a slight difference between what was presented here and what was presented by the Owners' Group only because I combined the small-break and large-break, as I mentioned. So, 65 of the 104 plants, approximately 63 percent of the fleet needed no adjustments, or new calculations. That's 27 of 35 BWRs, and 38 of 69 PWRs.

All 104 plants continue to satisfy the

2,200 degree peak clad temperature criteria. And I think that's important because most plants are limited by that criteria, as opposed to being limited by local oxidation. So, changes in local oxidation don't necessarily restrict operation because they're limited by 2,200.

Eight BWRs performed new LOCA calculations using existing approved methods and credit to the COLR TMOLs to reduce rod power to satisfy the new requirements. Here's an example of a tech spec COLR TMOL from a BWR.

This reduction in allowable rod power as a function of burnup is not related to LOCA, it's related to rod internal pressure concerns. So, the thermal mechanical operating limits are driving or requiring the power be lower at higher burnups for another reason, but you can take credit for it in LOCA space.

Thirty-one PWRs either performed new LOCA calculations or identified credits. Some of this is a repeat of what you presented so I won't spend too much time on it.

CHAIR ARMIJO: Well, I'd like to make sure you agree that those were okay to apply those credits.

MR. CLIFFORD: The next slide, when I talk about the audit. I think it's important to note that all the calculations were performed and documented in accordance with the vendors' Appendix B Quality Assurance Program. So, these weren't back of the envelope calculations, these were documented, these were validated, verified.

CHAIR ARMIJO: Good.

MR. CLIFFORD: With respect to breakaway oxidation, all plants exhibit margin of breakaway. As I mentioned, 103 plants predicted a time duration above 800 of less than 2,000 seconds. On this table you will see the measured breakaway times.

MEMBER REMPE: Is there a reason why the ZIRLO value is different than what it was in your letter in September? I mean, it's only 500 seconds, but you had an asterisk in your table and I was always wondering what the asterisk was for. And since we're way ahead of time and schedule, I'll ask what it's for. Then I noticed the time had actually changed.

CHAIR ARMIJO: It was 3,000, wasn't it?

MEMBER REMPE: It was 3,000 in the September -- and then there was like an asterisk in that table and I was just kind of wondering because I couldn't figure out what the asterisk is for.

MR. CLIFFORD: Maybe someone from Research wants to answer this. I mean, I could answer it, but I'm not sure I'd give the right answer.

MEMBER REMPE: A wrong answer is fully okay. Typo?

MR. CLIFFORD: No, it's definitely not a typo. I would say there's been more testing done on ZIRLO and there's been testing both by Westinghouse, and testing at Argonne.

CHAIR ARMIJO: Yes, I recall that. There was a difference of opinion --

MR. CLIFFORD: There was a difference of opinion.

CHAIR ARMIJO: -- between Westinghouse and Argonne, and there was more testing going on, but that's all I remember. And at some point it would be good to understand how he came to that number.

MS. FLANAGAN: Well, I'll say that the asterisk in the previous presentation was to identify that that value was under discussion. Why it's 3,500 seconds here I don't know. Is that -- because I didn't make that slide. I don't know. There hasn't been an agreement amongst everybody that there is a new value and that is reflected there. I think it's just still something that may come out in public comments that there's still more work to do to come to agreement.

CHAIR ARMIJO: At some point will we see a chart showing optimized ZIRLO, if that's the direction which the PWR -- at least Westinghouse is going with their -- for breakaway?

MR. CLIFFORD: Correct. To implement the final rule then each of the vendors would need to test their alloys --

CHAIR ARMIJO: Right.

MR. CLIFFORD: -- propose a breakaway time, minimum breakaway time. And we would review those analyses.

CHAIR ARMIJO: You'll have to agree that that's --

MR. CLIFFORD: Yes.

MR. RODACK: This is Tom Rodack from Westinghouse. Just to clarify on the ZIRLO time to breakaway oxidation, I haven't checked on this recently but the last time we spoke I think the agreement was that we would wait until the round robin testing had proceeded and the Reg Guide was more firmed up, and then decide on what the appropriate value is for ZIRLO. We still think the value is too low that's quoted here, so --

CHAIR ARMIJO: Well, you don't have to answer but I sure would like to know what the breakaway time for optimized ZIRLO is. Is it any different, or is it better, or what?

MR. RODACK: We've done tests that confirm that the breakaway oxidation time for ZIRLO and optimized ZIRLO are greater than 5,000 seconds. And we need to come to agreement on where those tests -- what the appropriate procedures and so forth, and that's the discussion.

CHAIR ARMIJO: Well, it would be pretty important to resolve that thing before this all gets settled.

MR. CLIFFORD: Absolutely.

CHAIR ARMIJO: Yes, because there's an awful lot of ZIRLO out there in the plants.

MR. CLIFFORD: There is, and this is a good exercise, but at the same time it doesn't influence the safety assessment because there are now PWRs that are close to 3,500.

CHAIR ARMIJO: No, I understand. I understand, but it gets to another point that I wanted to raise, and that's the issue of retesting and reporting on breakaway oxidation. And this is probably as good a time to raise that issue, is you've got a lot of margin to breakaway. And the breakaway picture that you show is really a demonstration of the effects of fluoride contamination on a particular Russian alloy. That's not radically different than zirc-niobium alloys that we might use, but it's -- fluoride contamination has long been known in the zirconium fabrication industry that it's bad news for normal corrosion in any reactor, and enormous amounts of care is taken to prevent that kind of contamination. An enormous amount of care is taken on all sorts of surface treatments on cladding because without that you can get highly variable performance under normal operating conditions, much less during accidents.

And there's also a lot of effort on change control because it's well recognized in the zirconium fabrication business that changes in processing, thermal processing, surface processing, etching, cleaning, all of these things can have a profound effect on just the standard operation of the fuel. So, there's -- every change goes through a qualification process. That doesn't mean that somebody couldn't make a mistake sometime, an error which would be a Quality Assurance issue, but as far as once the material is qualified and demonstrates significant margin, I don't see a justification for every reload to be tested as if this was a highly variable, uncontrolled material.

So, I just don't see where the justification is to require that. And the industry guys may think it's just fine, but I'll just tell you, I just don't see where it's -- it makes a lot of regulatory sense to require something like that.

Maybe a new material where you don't have much experience, even if it demonstrates margin, you may want to keep track of it for a few reloads or few years, but these pretty well known materials, I just don't see how you can require that kind of reporting.

MR. CLIFFORD: Well, as you mentioned, the vendor Quality Control process is aimed at oxidation kinetics during normal operation. It's not targeting what the oxidation kinetics are during a small-break LOCA, so they haven't added a test to their QA or Quality Control manufacturing process to account for this.

CHAIR ARMIJO: They will.

MR. CLIFFORD: Will now.

CHAIR ARMIJO: They will now because -- and that'll become just part of their normal Quality Assurance program. It's just another thing they've got to do. But to say -- and, obviously, they'll keep track of that. But for every reload to say we've tested this reload specifically for breakaway oxidation every time you get a new reload seems to be totally unnecessary. It's as if we required a specific chemistry test when we buy something to an ASTM standard, just -- okay, I've said all I want to say, but maybe other members of the Committee have a different -- want to add something there. It just seems like regulatory overkill.

MR. CLIFFORD: Right. Well, our position was the limited amount of testing that we had done identified that there were alloying effects. And even minor changes in alloy could affect the timing. I'm not saying it would go from 5,000 to 500, but it would change. And, also, that surface roughness and surface contamination had a big impact on the timing of breakaway. So, it's either that you do a very thorough experimental set where you investigate all of these variabilities and say okay, now that I've identified all the sensitivities, I can then build it into a QA process, so you don't have to run tests all the time if you don't vary those one or two that are limiting.

Or you do the opposite and say just test it before you put it in the reactor every time and that way I don't have to worry about defining what all the sensitivities are.

CHAIR ARMIJO: Well, remember that's a

sample. It's not -- what you really want to rely on is that the process is under control. And let me tell you what at least one vendor does, and I think it's typical of all of the fuel manufacturers, is when you have a process change, let's say you're going to go from belt grinding to chemical etch, big change.

That process change goes through qualification processing which it's varied. There's a standard procedure, then there's variations on temperature, the etchant, and concentration, so it goes through a rather very broad testing to see if you're on the edge of a cliff which relates to normal corrosion. They test in steam, they test in water, and in this case they would add a test or breakaway. And they qualify the material, and they qualify the process. And if they change the process, they'll go through it again.

Now, what you've got to watch out for are creeping changes that nobody spotted, and that's a Quality Assurance thing, that's a change control process, but -- and I could see if you were right on the edge of margin, instead of 5,000 -- your ZIRCALOY-2 having greater than 5,000, you were right up at 4,500, I'd say yes, you've got to keep a really close -- you almost have to test each batch to be sure. But when you have this much margin on a well known material and a very controlled fabrication process, it just seems excessive.

MR. CLIFFORD: I'm sure we'll get similar comments from the industry.

CHAIR ARMIJO: Well, I don't know. It's up to them. I'm not in the business any more.

MEMBER REMPE: Well, if they did they could come in and ask for an exemption, and you'd review the whole process.

MR. CLIFFORD: Well, this is still a draft rule.

MEMBER REMPE: Right.

MR. CLIFFORD: If they provided significant comment and could backup some of these strategies for insuring that the cladding doesn't become more susceptible, then we would consider them and maybe alter the rule when it goes final. I mean, that's the purpose of a draft rule is to go out there and let everybody provide comment, and tweak as necessary.

CHAIR ARMIJO: Okay.

MEMBER SHACK: I mean, I thought the original motivation was the one you described. You really weren't quite sure what the mechanism was, and until you're confident that you've controlled every variable that could affect it --

MR. CLIFFORD: Right, and this margin is really a snapshot in time. I mean, plants could make some changes or there could be a new LWR design that comes in that say has a time above 800 at 4,000 seconds. I don't know what the future is going to bring.

CHAIR ARMIJO: You know, I think you would -- you know, the closer you are to the margin, the more you have to control it. It's as simple as that. When you're far away from margin, that's -- I'm repeating myself, so let's move on.

MR. CLIFFORD: Okay. As I mentioned, the Staff conducted audits at the local offices of each of the vendors to confirm -- first of all, we confirmed that what they were assuming for analytical limits, in other words, what targets they were shooting for were acceptable, and that they were accurate and supported by data. And that really goes down to the hydrogen pickup models.

We also evaluated the quantification, justification, and application of the analytical credits. For instance, a good example would be six of the PWRs large-breaks credited, the transition or the potential transition from Appendix K to a Best -- or realistic model. So, maybe they said okay, there would be a 50 percent reduction -- if I had rerun my analysis using one of these available realistic models, it would be a 50 percent reduction.

During the audit we made sure that okay, well that 50 percent was actually a minimum credit they could get based upon a wide spectrum of plants that already had demonstrated that that 50 percent existed. In other words, it would look at every plant that went from Appendix K to Best Estimate, what the deltas were, and that what they were assuming in the analysis was --

CHAIR ARMIJO: It passed the sanity check.

MR. CLIFFORD: That was reasonable and it wasn't the maximum. We reviewed a sampling of the new LOCA calculations in order to identify any changes to the approved methods and models. And, finally, we compiled plant-specific information to evaluate each individual plant with respect to margin.

We created what we're calling the ECCS margin database. It's an Excel spreadsheet that was made available for this meeting. I don't know if you've had a chance to look at it.

CHAIR ARMIJO: Yes.

MR. CLIFFORD: It's pretty comprehensive.

It goes through each of the -- plant by plant what the current analysis of record, what cladding material they are using, what sort of margin they're crediting, and what their margin to the new requirements would be.

Now, for the existing fleet our individual plant safety assessment confirms and documents a continued safe operation for the entire fleet. We also evaluated the future operation of Watts Bar 2 and potential startup of Bellefonte Units 1 and 2 with respect to post quench ductility and breakaway.

But, in general, you know, the industry is moving off of these old zirconium claddings and they're moving on to advanced claddings, not to make themselves have more margin for LOCA. They're doing it for other reasons, but the net result is these new cladding alloys have significantly improved corrosion resistance. So, I'm not saying that this goes away, but if you look at some of these advanced cladding, if you end up with less than 100 ppm hydrogen uptake at your end of life, you're pretty much around 17 percent, so it's not a big change.

CHAIR ARMIJO: Full circle.

MR. CLIFFORD: Yes, right. We also evaluated the DCDs that are under review or have been approved. This table here provides the calculated peak clad temperature and ECR for four of the advanced designs.

In general, the advanced designs have enhanced ECCS capabilities, so that LOCA is not as limiting as it is for the current fleet.

MEMBER SHACK: Until they do their uprates.

(Laughter.)

MR. CLIFFORD: But also remember when these plants startup, they're going to be starting up with the latest and greatest cladding alloy. They're not going to be starting up with some of the alloys that a higher hydrogen pickup.

CHAIR ARMIJO: In these assumptions you use the old standard materials like for the --

MR. CLIFFORD: No, these results were just right from the design certification documents. Like for instance, ESBWR there's no uncovery or heat up.

CHAIR ARMIJO: Yes.

MR. CLIFFORD: The other one, the peak clad temperatures are all below 1,900 and the ECRs are very low.

CHAIR ARMIJO: Right.

MR. CLIFFORD: So, they all have a lot of margin to what you would expect with the cladding alloy they'd be using. So, all I'm trying to say is that the advanced reactors have significant margin.

Now, the plant safety assessment is really a snapshot in time. We took the current analysis of record, we said where are they relative to what the research data, and we showed that there was sufficient margin. But, once again, it's a snapshot in time. How do we insure that going forward that before the new rule is implemented that they don't migrate into an area where they have less margin or no margin?

But I think it's important to recognize that plan changes which could impact the margin assessment would most likely involve a license amendment request. I mean, what's going to impact your LOCA analysis would be a major plant modification like new steam generators, a power uprate, a change in fuel vendors or fuel design, or changes in LOCA methods. That's what's going to impact your LOCA analysis of record, and then potentially impact the amount of margin you have.

And when a new license amendment request comes in that gives us a vehicle for then asking the question, how does this impact how much margin you have relative to the data, since you haven't transitioned yet?

And with respect to unplanned changes, we have the existing 50.46(a)(3) reporting requirements. Now, this is the 30-day notice, or the annual notice that we get from each of the licensees if they were to discover an error or make a change to their model. So, we get periodic updates that let us know whether or not they've changed their analysis of record. If they haven't changed their analysis of record in that year, then we know the margin assessment is still valid. And if it has changed, we have a vehicle to then ask the question.

So, how we're going to use this information is really -- the next slide. This is kind of our action plan. If it takes five or six years, or ten years, or however it long it takes to implement these new requirements, we're going to follow this action plan to make sure the plants continue to be safe.

And the first is, on an annual basis we're going to update the ECCS margin database. That doesn't mean that we're not reviewing it all the time. I'm just saying on an annual basis, we'll just pick a date, September 1st say and just update the margin assessment database. On a continuous basis we'll scrutinize any 30-day reports that were received which would be more than 50 degrees. If it's less than 50 degrees, it's probably not going to impact how much margin you have because none of these plants are that close. But if it's several hundred degrees, we'll have to question that. But we have a vehicle for doing that.

On a continuous basis each time we receive a license amendment request, we'll ask about existing margin, and the continued applicability of the margin assessment.

And, finally, we conduct annual meetings with the fuel vendors where we go through pretty much everything that's fuel-related, new topical reports, new cladding materials, new alloys, fuel performance. And during those meetings we can use those to get a feel for what's changing, what's down the road. Who's doing an uprate, how all that impacts --

CHAIR ARMIJO: You also visit their factories and go over their processing and things like that, don't you? You get a chance to talk to them about their -- literally, their Quality Control on issues like this.

MR. CLIFFORD: Well, we certainly tour their facilities, and we're well aware of their facilities. I believe Region II, though, has the responsibility of their Appendix B-type fuel-fab program.

CHAIR ARMIJO: That's an ideal place to find out what kind of process changes are going on that would affect --

MR. CLIFFORD: Exactly. Okay, conclusions. The Research identified new embrittlement mechanisms which need to be addressed. Based upon our assessment, a majority of plants need no new calculations or analytical adjustment to show margin for these potentially new requirements. The margin database confirms and documents on a plant-specific basis the continued safe operation of the existing fleet. And the Staff will continue to confirm plant safety until new regulations have been implemented.

CHAIR ARMIJO: Any questions from the Committee?

MEMBER SHACK: There was a statement that the new rule was going to address Mr. Lacey's petition, and I haven't seen anything that really does that. Is it something in the Statement of Considerations?

MR. CLIFFORD: There was an analytical requirement added to the rule itself that said the effects of crud have to be accounted for.

MEMBER SHACK: I missed it. I missed it.

MR. CLIFFORD: So, any new LOCA model we review they would have to say how are they accounting for crud.

MEMBER SHACK: I missed it.

CHAIR ARMIJO: Paul, don't most of them already do that?

MR. CLIFFORD: A lot of them. I can't say -- there are a lot of LOCA models dating back decades some of them. A lot of them do.

CHAIR ARMIJO: Yes.

MR. CLIFFORD: I can't say that they all do.

CHAIR ARMIJO: Okay.

MR. CLIFFORD: But they may not specifically account for it, but the way you measure oxidation layers, sometimes you get the tenacious crud that's mixed in with the oxide when you do your eddy current testing.

CHAIR ARMIJO: Yes.

MR. CLIFFORD: You get a combination of the two, so when you adjust your oxidation model you're kind of getting the inherent -- some inherent effects of tenacious crud.

CHAIR ARMIJO: Yes. Yes. Is that it?

MEMBER BLEY: This is Dennis Bley. I have one question about the database you gave us. Are the results that are in there based on the Owners' Group calculations that we heard about from them earlier?

MR. CLIFFORD: Yes.

MEMBER BLEY: Okay, so these aren't what I call real margins. These are margins adjusted for the kind of calculations they explained to us.

MR. CLIFFORD: Correct.

MEMBER BLEY: Enough to show margin, but not enough to really define what the margin is. To set a bound on the margin.

MR. CLIFFORD: Correct.

MEMBER BLEY: Okay, thanks.

MR. CLIFFORD: Right. It's a minimal amount of margin necessary to meet the research data. Were there any more questions on the database itself?

CHAIR ARMIJO: No, good job.

MR. CLIFFORD: The next presentation involves the implementation plan, and it really builds on what we learned from this margin assessment.

CHAIR ARMIJO: Yes. What I'd like to do is just poll the Committee. We're well ahead of schedule, but we're getting close to noon and we have the implementation presentation, then we have some

Committee discussion. And how do you guys feel about just adjourning for lunch and coming back at -- pick a time, 1:00 and wrapping it up? We were supposed to go to lunch between 1:30 -- I'm sorry, between 11:30 and 12:30, so we could come back at -- give ourselves another 5 minutes, come back at 1:00 and wrap this up? I don't really want to push through lunch.

MEMBER REMPE: But he only has 10 slides in his next presentation. It's up to you all. I'm willing to do either.

CHAIR ARMIJO: Well, you don't have to leave until 3:00.

MEMBER REMPE: Right. I'm good either way. It doesn't matter. It's just that it's a fairly short presentation.

CHAIR ARMIJO: Well, just for continuity, because then -- why don't we just take a lunch break and regroup at 1:00. Okay, so we'll have an hour and 15 minutes for lunch, and then we'll wrap everything up, and you can go home, and we'll be done.

MEMBER SHACK: Well, if Joy's got a 3:00 flight --

MEMBER REMPE: No, I have a 5:00. I have to leave here about 3:00 or so.

CHAIR ARMIJO: Yes, she's got it at 3:00.

MEMBER REMPE: So, I've got plenty of time either way. I just thought --

CHAIR ARMIJO: Okay, so why don't we do that? We'll reconvene at 1:00.

MEMBER REMPE: Great.

(Whereupon, the proceedings went off the record at 11:43:18 a.m., and went back on the record at 12:58:16 p.m.)

CHAIR ARMIJO: Okay, let's resume. And we are now on Implementation Schedule. Paul is going to present that.

MR. CLIFFORD: Okay, welcome back. I've got a handful of slides I'm going to go through, but as I'm going through it, it may be helpful to kind of --

(Simultaneous speech.)

CHAIR ARMIJO: Get out the big gun.

MR. CLIFFORD: And this will give you a feel as I walk through it how it all falls together, and how much work there is.

(Off the record comments.)

MR. CLIFFORD: We're just going to talk about the work scope, the overall implementation strategy, and then how it all comes together for the existing fleet, and for new plants.

This slide is just intended to illustrate the potential scope of work that needs to be completed by the industry and the NRC to implement this rule. We don't have to walk through all of them, but you can kind of see the magnitude of work. And I highlighted in blue the actual plant-specific LOCA analysis, preparation of any license amendment request, and then Staff review as being an exceptional amount of work, more so than updating a single model.

Don't get me wrong, it takes some effort, but then implementing that model across 50 plants is a significant effort. So, we've kind of devised a strategy to limit that one particular aspect of the implementation, and I'll get to that.

Based upon comments we received in the ANPR which identified workforce limitations to complete a parallel analysis stream, we came up with a staged implementation plan as being the most effective and efficient way to implement 50.46c.

Our original intent was that plants with the least available safety margin would be required to be in compliance at the earliest date. And this shows you Track 1 would be the least amount, Track 3 would be the most available margin. And this would be informed by the safety assessment that we completed.

MEMBER SHACK: We've just agreed it doesn't really show the actual margin. They just carried it out far enough to demonstrate margin.

MR. CLIFFORD: Right. Well, I'll get to that point. Next is you need to recognize that the plants with the least amount of margin are going to require the most amount of effort, and probably the longest calendar time to demonstrate compliance. And that as we learned earlier, there's a substantial number of plants that don't have to do a lot of re-analysis to show compliance. So, why would you want the 60 or so plants that could be in compliance now to wait years for the handful of plants that have to do a lot of work?

So, you still -- so, we tried to combine those two thoughts. Let's try to get as many plants into compliance as fast as we can, but at the same time give more time to the plants that need more time to update models and methods.

So, we balanced those two initiatives and we came up with a plan that, one, expedites the implementation as soon as possible on as many plants, still maintains a prioritization except now it's between Track 2 and Track 3, and balances the work load. We drew lines on the number of analysis so that we could balance the workload between Tracks 2 and 3.

And what we came up with is summarized in this table.

There's three tracks. The first track would be plants that do not need any new analysis or changes to their existing LOCA models or methods. We anticipate that the level of effort is low, and we've identified 27 BWRs and 38 PWRs that fall into this category.

The second implementation track is plants that we feel have the least inherent margin. And those are plants that require analytical credits in combination with realistic LOCA models. And then we divided by BWRs between BWR-2s and 3s, and we felt BWR-2s had the least amount of margin so we moved them into Track 2.

And Track 3 is the PWRs that required some analytical margins, but at the same time used Appendix K. So, we knew there was a lot of inherent margin in an Appendix K analysis. So, although they may not have credited all that margin, it's available. So, we lumped in those plants with the BWR-3s. And you may see differences, there are 16 plants on Track 2, and there's 23 plants on Track 3, but if you look at the number of multi-unit sites, it turns out to be the identical number of analyses that have to be done. Any questions on that?

(No response.)

MR. CLIFFORD: Okay. Ralph is going to go through these next two slides, because I know he's been wanting to talk.

(Laughter.)

CHAIR ARMIJO: Okay.

MR. LANDRY: Okay. When we started looking at how to implement the new regulation, we started looking at where are plants with regard to licensing today, and said we have plants in various stages. We have plants that are already licensed.

First we said okay, we've got the operating plants, those are already licensed. And we have the new reactors. And then we started going through the new reactors and saying with the new reactors we have probably ever possible permutation and combination you could get. And then went back and looked at the operating reactors or the old reactors and said what we really need to do is break this down into Part 50 reactors, and Part 52 reactors, because under the Part 50 plants, we have those who are operating. We have those that have now reinstated or resumed their construction permits.

How do we apply this regulation to those plants and said well, we have to consider those that have construction permits issued after the effective date of the rule under Part 50, and say those plants have to be in compliance with the rule when they come in.

On the other hand, those operating licenses are issued based on a construction permit already in effect, which is really only two plants today. They have to comply with the requirements of the rule according to the dates set forth in Table 1, which Paul has gone through that whole table and tracking system.

Those whose operating license were issued prior to the effective date of the rule have to come into compliance according to Table 1, the layout of the multi-track system. And those with operating license issued after the effective date of the rule have to comply with the conditions of the rule.

So, this separates a little bit those that are already under an old construction permit from those who might get a new construction permit under Part 50. And we put this in because some of the advanced rectors, not the new reactors, but some of the advanced reactors are saying they might come in under Part 50 instead of Part 52, even though right now the plan is that they will be reviewed in the

Office of New Reactors, but they will be Part 50 plants. So, they will have to go through the two-step process of a construction permit followed by an operating license.

So, we tried to go through the logic of the plants that exist today and plants that are being built today, the plants that would be under Part 50, this is one group. Now we're going to look at the Part 52. And what is in the proposed regulation today for the Part 52 plants is significantly different than what it was four months ago, because we have changed this a couple of times trying to figure out what is the most streamlined way to approach the Part 52 plants?

And this becomes complicated because we have plants that have design certifications already approved. Some of those will probably never be built, some of those will be built, some of those are going to have to get a certification renewal before they can get built. We have certifications in for review today that are nearing completion that have combined license applications associated with them which will be completed before this rule is approved.

We have some certifications that we project out won't be approved until after the effective date of the rule. And we have some that will no doubt come in after the rule is effective. So, how do we make sense out of this group?

We in the Office of New Reactors felt very strongly that the new reactors should not be treated according to Table 1, or any kind of requirement that they have to comply with the rule immediately if they're already in the stream, because they will not have fuel that has been exposed.

A new reactor is going to, by definition, have completely clean fuel. It's not going to be a reload core with partially burned fuel, it's going to be a completely clean core. Plus the fact that a lot of the plants that are in for certification we know are going to have different fuel when they actually start to operate than the fuel that's reviewed for their certification.

So, how do we make sense out of this? Well, we came back and said okay, all applications docketed after the effective date of the rule, that means design certifications, combined licenses, you come in after the effective date of the rule, you comply with the rule.

Those standard designs renewals that are sent in after the effective date of the rule; in other words, if some plant that's on the shelf right now does not have to have a renewal until after the effective date of the rule, that design certification renewal must comply with the rule.

Standard design applications pending at the effective date of the rule, those that we have right now, assuming that AP1000 will be complete before the effective date; there's pretty good indication of that. If we have one of the others that's in, the design certification gets in before the effective date, is pending at the effective date, they have to comply with the conditions of the rule when a renewal is submitted, so that if US-APWR is not completed by the time the rule is final, the US-APWR design certification would not have to comply with the rule until it submits a renewal.

The combined licenses that are docketed after the effective date of the rule have to comply with conditions of the rule. It's a pretty simple requirement. But the combined licenses that have been docketed or issued -- now that means if you get in before the rule is final, or you're in and you get your combined license before the rule is final, you don't have to comply with the rule until your first refueling outage. You can refuel the plant, but before you can start the plant up again, you now have to be in compliance with the rule.

So, that's saying if Vogtle gets their COL, they get the plant built, and then the rules come in, they don't have to meet the rule until they refuel the plant. When they refuel it before they can start back up they have to be in compliance. And we're covered on all these plants anyway because all of them still have to meet 50.46.

When we look at all the different plant states that you could mix together here, we tried to find what was the most rational way to handle all the combinations and permutations that could exist. It makes it very complex, and it could be very confusing to work through and say I have a plant, where does my plant fall in this implementation plan? But we're trying to do it in a fair manner. And sometimes people say well, you're the NRC.

CHAIR ARMIJO: Ralph, I'd like to ask you a question.

MR. LANDRY: Seriously, we tried to look at all the conditions that you could have, and we tried to find what is a logical way to treat them.

CHAIR ARMIJO: Let me ask a question. Let's hypothesize that you had ESBWR certified. Now, based on the design the core is never uncovered. You don't get peak clad temperatures. Does this rule apply to the ESBWR?

MR. LANDRY: Yes, the rule will still apply.

CHAIR ARMIJO: Do they have to do anything?

MR. CLIFFORD: It would be simple for them to show compliance, but they would still have an analysis that shows they don't uncover, so they're still calculating --

CHAIR ARMIJO: That's part of the certification that's been done.

MR. LANDRY: But you have to keep in mind if they get their certification before the rule is final, they don't have to comply with the rule until they come in for a renewal. They have 15 years from the date of certification until they have to renew.

CHAIR ARMIJO: But that's not the first reload then. It's not --

MR. LANDRY: But a plant referencing them falls into the operating combined license group. Now, they have to comply according to when they get their COL.

MR. CLIFFORD: It's compliance of the licensee versus compliance of the design.

CHAIR ARMIJO: But the licensee would reference the design and say we don't uncover the core.

MR. LANDRY: But you're still covered by the rule.

CHAIR ARMIJO: Yes, but they'd be able to say we don't uncover the rule, we comply with the rule by virtue of the fact we don't uncover, and we're certifying that --

MR. LANDRY: Well, they have to show it somehow.

MR. CLIFFORD: It would be on the analysis. They would not have to repeat the analysis because it shows that they're --

CHAIR ARMIJO: Unless something changed a lot.

MR. LANDRY: Keep in mind, Sam, that once every operating reactor has implemented the regulation, 50.46 goes away and is replaced by 50.46 what is now (c), we'll drop the (c), and that will be 50.46.

CHAIR ARMIJO: Right.

MR. LANDRY: So, you have to be in compliance with something. If you're in compliance with the regulation on the books today and that regulation goes away, what do you do?

CHAIR ARMIJO: Yes.

MR. LANDRY: You have to come into compliance.

CHAIR ARMIJO: Okay.

MR. LANDRY: Now, this gets really messy when we look at --

CHAIR ARMIJO: It sure does.

MR. LANDRY: -- all these conditions, and we look at -- we don't want all of these different regulations on the books. Eventually, we want one regulation.

MR. DUNN: Dr. Armijo?

CHAIR ARMIJO: Yes?

MR. DUNN: Could I ask one question?

CHAIR ARMIJO: Sure. Can you state your name for the record.

MR. DUNN: My name is Bert Dunn. I'm from AREVA. Thank you.

In the case that we just brought up where we've got a BWR that never uncovers the core, are you still going to apply the breakaway oxidation testing to the fuel, things that apply that the plant will be using, or would you wind up making an exception for that point? It's a little bit ridiculous for a plant that's never going to go over 600 degrees testing for breakaway oxidation.

MR. CLIFFORD: I agree, but it's unlikely that that plant will use a unique cladding type, so there will be -- if it's using M5, first of all --

(Simultaneous speech.)

MR. DUNN: -- tested every reload. Right?

CHAIR ARMIJO: Well, that's something that should be raised in the public comment.

MR. DUNN: Okay.

(Simultaneous speech.)

CHAIR ARMIJO: The specific issues that you've got to take --

MR. LANDRY: Bring it up in the public comment, but there always the exemption route also.

CHAIR ARMIJO: But exemptions are painful processes, at least to somebody. One of the reasons we're doing this is because too many exemptions.

MR. LANDRY: Well, we've tried to make the implementation and application of the regulation as uniform and as logical as we could. And you can probably go out and find some exception to it if you really want to.

CHAIR ARMIJO: Yes, I understand that. You know, there's a lot of complications. Certainly, we're not going to sort this out, you guys do this all the time.

MR. CLIFFORD: I don't have a slide listing Table 1, but it was provided in the handout. This just lists all of the plant -- identify all the plants that fall into this implementation logic. I wanted to clarify something here.

Even though we're moving the Track 3 plants, the ones with the most margin to the beginning, that doesn't affect the implementation schedule for Track -- for the Track 1, Track 2 as labeled here.

(Simultaneous speech.)

MR. CLIFFORD: -- limited by first you've got to do the models, get the models approved, and then do the analysis. So, it's going to take as long as it's going to take. And by moving these 65 plants in front of them, that doesn't necessarily push those further down in the implementation schedule. I think that's important to say.

And another thing is, at the beginning I mentioned that the blue highlighted text here represents a significant amount of work. I'll give you an example. Okay, there's a plant out there that's using an Appendix K model that's calculating 1 percent

ECR. So, in theory to show full compliance they would have to -- some of them would have to come in with a revision to their Appendix K model whereby they would update it to include a Cathcart-Pawl calculation of local oxidation which is the equation you need to integrate time at temperature to be consistent with the experimental database. And they would need to have an alloy-specific hydrogen update model -- uptake model, sorry.

So, they would need to get those models approved. Then they would redo their LOCA analysis, calculate integrate time at temperature with both Baker-Just and Cathcart-Pawl, compare their Cathcart-Pawl ECR to the allowable value for their given alloy-specific hydrogen model, generate a license amendment request, and then submit that to the NRC, and then we would review that.

Now, that's a significant amount of work for a plant that's calculating 1 percent now. So, one idea we were pushing, and we started to include in the Statement of Considerations was a way to avoid the license amendment request for the Track 1 plants.

We would review and approve each hydrogen uptake model and the licensees in Track 1 would simply just refer to it, update their FSAR to capture that they're in compliance now, and they're using approved methods. And we wouldn't review the plant-specific application of those models.

CHAIR ARMIJO: Paul, that sounds like a very good idea, but I'm hung up on the hydrogen uptake models for the conventional materials that we're currently using.

Who actually submits that? Different people make Zircaloy-2, different fuel vendors. Is it going to be a combined hydrogen uptake model, is it going to be an NRC hydrogen uptake model? Don't we have enough data now to literally say this is it? The same goes for the other alloys.

MR. CLIFFORD: We have -- based upon information that's available in the public domain, we've developed hydrogen uptake models for each of the cladding alloys, and we have them built into FRAPCON right now. But we would expect that each of the vendors would use both a combination of proprietary and publicly available data to come up with the best hydrogen model that they could and submit it. We would approve it, and with that approval they would provide a chart of allowable ECR versus burnup for each of their alloys. We would approve that, so now we've approved the new limits, analytical limits for each of the plants.

CHAIR ARMIJO: What if the vendors said we'll use your FRAPCON hydrogen uptake model, and we won't take exception to it, would that be acceptable?

MR. CLIFFORD: That's a good question because we said at the beginning of this exercise with the Owners' Group that we would allow them to do that for this margin assessment, but we would expect that they would supplement that database with data they have -- we believe that they have available that's not publicly available. Everything in FRAPCON has to be publicly available.

CHAIR ARMIJO: I understand that.

MR. CLIFFORD: We expect that they have a larger database available to them to improve upon the models. Plus our models are somewhat simplistic as we've taken all the data as a function of burnup. You really don't want corrosion models as a function of burnup. Burnup is not the correct dependency.

CHAIR ARMIJO: No, it's exposure time.

MR. CLIFFORD: It's exposure time.

CHAIR ARMIJO: Right.

MR. CLIFFORD: I mean, the last two years a fuel rod is in the reactor for its third cycle. It's only getting five or six gigagwatt days, but it's in their for two years.

CHAIR ARMIJO: Right.

MR. CLIFFORD: Whereas, in the first two years it's getting 24-gigawatt days. So, burnup is not the right variable there. So, they would probably come in with more of a fuel duty or time at temperature model.

CHAIR ARMIJO: Do you perceive that different vendors would have different hydrogen uptake models for the same alloy?

MR. CLIFFORD: Absolutely.

CHAIR ARMIJO: AREVA, Zircaloy, Westinghouse, Zircaloy.

MR. CLIFFORD: Absolutely.

CHAIR ARMIJO: GE --

MR. CLIFFORD: They have different thermal treatments, and the thermal treatments can affect the corrosion.

CHAIR ARMIJO: That would be your logic for that.

MR. CLIFFORD: Yes.

CHAIR ARMIJO: Okay.

MR. CLIFFORD: I think we've seen enough data to know that the Westinghouse BWR Zirc-2 has a different hydrogen uptake than say the GE Zirc-2.

CHAIR ARMIJO: Okay. All right. So, I see why this thing is not done already.

MR. CLIFFORD: That's what I was --

CHAIR ARMIJO: You had enough to do this assessment but it's not really good enough, in your opinion, for --

MR. CLIFFORD: Correct.

CHAIR ARMIJO: -- an amendment, or even the Track 1 analysis, or do they need that?

MR. CLIFFORD: No, I believe they're going to have to submit hydrogen uptake models for each of the alloys before Track 1.

CHAIR ARMIJO: Okay.

MR. CLIFFORD: Is there any questions --

MEMBER SHACK: Well, I guess, I mean you can use that, you can use it as some sort of a bounding model. I presume you could include it into your Best Estimate or your realistic calculation as part of the sampling process. You'd have a statistically-based model. There are lots of permutations one could get into here.

MR. CLIFFORD: That is true. That is true.

MEMBER SHACK: And I could envision Appendix K guys looking for a bounding model, realistic people looking for distribution models.

CHAIR ARMIJO: Right.

MR. CLIFFORD: If they would statistically sample hundreds of cases, each one would be a different rod at a different burnup with a different hydrogen model -- a different amount of hydrogen in it, and a different allowable ECR --

MEMBER SHACK: Well, I haven't thought through whether it's sensible to do that, or just what the sampling would look like.

CHAIR ARMIJO: Well, it's a long schedule.

MR. LANDRY: We're saying in theory yes, that's possible. It all depends on what the vendor wants to do. If they want to take enough data to support a PDF, or do they want to just use a bounding number? We're not telling them what to do.

MEMBER SHACK: If you don't have enough data for a PDF, it's hard to know that you've got a bounding value.

CHAIR ARMIJO: Yes.

MR. LANDRY: When they come in we'll review it.

CHAIR ARMIJO: Yes. Okay, I understand what you're doing.

MR. CLIFFORD: But, also, the variability in measured hydrogen actually and circumferentially is tremendous, but that's on alloys that have a lot of hydrogen. When you get to the more advanced alloys that are only picking up 100 or 200 ppm, that variability is not that big of a deal any more.

CHAIR ARMIJO: Yes, who cares? Yes, so it all depends how long it takes to put these packages together and you could clear out Track 1 pretty quick.

MR. CLIFFORD: Yes.

CHAIR ARMIJO: But is that your proposed plan, not requiring license amendment requests for the Track 1 guys?

MR. CLIFFORD: That's what we're going to put in the Statement of Considerations.

CHAIR ARMIJO: Okay. All right. Any other questions? Joy? Bill? Dennis, are you on the phone?

MEMBER BLEY: Yes, I am, Sam.

CHAIR ARMIJO: Do you have any questions or comments on Paul's presentation?

MEMBER BLEY: No. They're right, it's very complex.

CHAIR ARMIJO: Do you have the big chart?

MEMBER BLEY: Yes, I have it. I'm looking at it.

CHAIR ARMIJO: All right. We're all staring, but I think it lays it out. It's a lot more work than I thought was needed. Okay.

All right, Paul. Have you presented everything you want to do? All right. Before we go into Committee discussion, is there anyone on the -- in the room who would like to make any comments, members of the public, Staff, anyone?

(No response.)

CHAIR ARMIJO: Okay. Let's open up the bridge line and see if anyone is on the bridge line that would like to make a comment.

MR. CLEFTON: This is Gordon Clefton, NEI on the bridge line.

CHAIR ARMIJO: Okay. I'm sorry, I didn't hear the last name.

MR. CLEFTON: Last name is Clefton.

CHAIR ARMIJO: Clefton?

MR. CLEFTON: Gordon Clefton.

CHAIR ARMIJO: Please go ahead.

MR. CLEFTON: Yes, sir. I'd like to compliment Paul for the great job that he did in recognizing how complex the issue is, and encouraged to see the NRC cooperation that we've had in the past year to get to the level we are now.

Of course, we have quite a bit of ways to go. Paul and I have talked in terms of workshops and public meetings to insure data transfer in the spring, and we certainly encourage that activity to continue and look for your endorsement of it.

CHAIR ARMIJO: Very good, thank you. Is there anyone else on the bridge line that would like to make a comment?

(No response.)

CHAIR ARMIJO: Okay, hearing no comments we'll just close the bridge line and I'll just now turn to Committee members if they want to make any closing remarks or observations, or things that you might suggest the Staff consider for the presentation in January. We have let's see, January 19th or 20th?

MR. CLIFFORD: I think it's the 19th.

CHAIR ARMIJO: The 19th we have a full Committee. And, obviously, we don't have as much time, but -- so we'll have to really condense this down, but I think you've got a very solid presentation so I don't think it's going to be much of a problem. But let's start with Joy.

MEMBER REMPE: I just wanted to thank the Staff. I thought the presentations were well organized, and I learned a lot, even though we viewed this previously, it just was a nice overview and I appreciated it.

CHAIR ARMIJO: Bill?

MEMBER SHACK: No, I think they're working hard to get through a fairly complex sort of thing in a fairly effective and efficient manner. When will the Statement of Considerations be available?

CHAIR ARMIJO: We haven't received them yet.

MEMBER SHACK: Yes, at least as far as I know we haven't received them. And then there's apparently lots of interesting goodies in there.

MS. INVERSO: That usually gets released to the public at the same time the SECY Paper does, so the rule is due to the EDO on February 29th, and then to the Commission on March 14th, so I would imagine it would be sometime after that. And that's not for comment, just publicly available within ADAMS.

CHAIR ARMIJO: How about for us prior to our January 19th meeting?

MS. INVERSO: We could talk and --

CHAIR ARMIJO: Sneak one over?

MS. INVERSO: -- try to arrange something. I would have to talk to with my management and working group, but --

CHAIR ARMIJO: Yes, just consider that a request on our part.

MS. INVERSO: Okay.

CHAIR ARMIJO: Is that it, Bill?

MEMBER SHACK: Yes, I think so.

CHAIR ARMIJO: Okay.

MEMBER SHACK: Well, I guess the only other thing is -- well, I guess if I see the Statement of Considerations whether there needs to be any further consideration of this long-term cooling criteria, whether everybody agrees to use what's been used for the GSI-191. I suppose that would make life simpler.

CHAIR ARMIJO: Right.

MEMBER SHACK: But at least it would be nice if there was a good -- well, I'm not sure how that was justified in the GSI-191. I guess there was data, and if that data -- okay, that would be made available.

MR. CLIFFORD: Right. And it's my understanding that was long-term steam oxidation tests, but it was all proprietary.

CHAIR ARMIJO: Yes. Well, look, I'd like to add my compliments to the Staff and also to the industry for very good presentations, but also as important the ability to work together to address a real problem, real issues, and cut a lot of wasted time and effort by avoiding the need for a Generic

Letter. I thought that was terrific.

I think you're well prepared for the full Committee presentation. I think the focus should be on the rule itself, the rule language and what it means. And, of course, the assessment -- your assessment of what the findings from the audit and the industry submittals, and then the implementation, I think it will be tough to get all of that in in two hours, but actually it may not take that long, as much time as I think. But I think that's where your focus should be.

I wouldn't spend much time on the Reg Guides. We've seen them before. Maybe it's --

MR. BROWN: One and a half hours.

CHAIR ARMIJO: Is it one and a half? Okay, well then don't spend any time on the Reg Guides and say you guys have got to remember what --

MEMBER SHACK: There will be Reg Guides.

CHAIR ARMIJO: There will be Reg Guides, and we're working on them. But overall, I think the Staff has done an excellent job in handling a complicated problem. I think we'll be better off for it.

You've heard my comments on the breakaway oxidation, the need for periodic testing. There's got to be a better way to do that, but that may or may not be what the rest of the members of the full Committee think.

As far as a letter, it's really up to the Staff to either request a letter from us, or say -- and if you don't really need one, just let us know at the full Committee meeting. I can't guarantee that we will do what you request, but we will take it into consideration. That's the best I could say.

I'm very pleased with this meeting. I think everybody has done a really good job, and I think made a lot of progress. So, with that, unless there's any other comments.

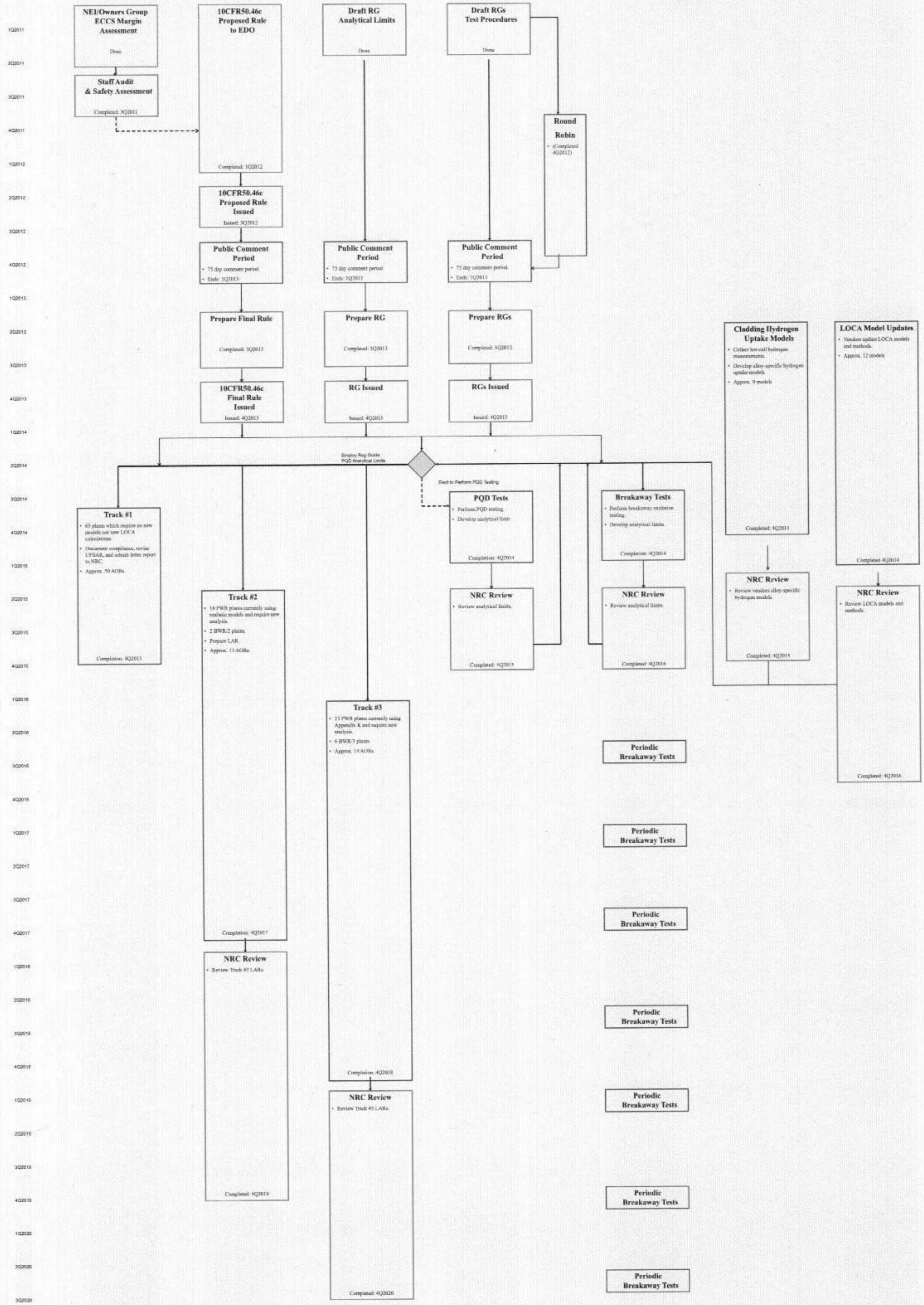
MR. NGUYEN: Dennis is on the phone.

CHAIR ARMIJO: Dennis? I'm sorry, Dennis, I didn't -- I overlooked you because you were not here. But if you would like to make some comments.

MEMBER BLEY: Me, no. I just -- after everything everyone else said, I was a little surprised by how complex this process is, but I guess that's just the nature of it.

CHAIR ARMIJO: Okay. With that, I'd like to thank everybody and the meeting is now adjourned way ahead of schedule.

(Whereupon, the proceedings went off the record at 1:35 p.m.)



1Q2011
2Q2011
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4Q2019
1Q2020
2Q2020
3Q2020
NEI/Owners Group ECCS Margin Assessment
Done
Staff Audit & Safety Assessment
Completed: 3Q2011
10CFR50.46c Proposed Rule to EDO
Completed: 1Q2012
10CFR50.46c Proposed Rule Issued
Issued: 3Q2012
Public Comment Period
• 75 day comment period.
• Ends: 1Q2013
Prepare Final Rule
Completed: 3Q2013
10CFR50.46c Final Rule Issued
Issued: 4Q2013
Draft RG Analytical Limits
Done
Public Comment Period
• 75 day comment period.
• Ends: 1Q2013
Prepare RG
Completed: 3Q2013
RG Issued
Issued: 4Q2013
Draft RGs Test Procedures
Done
Round Robin
• (Completed 4Q2012)
Public Comment Period
• 75 day comment period.
• Ends: 1Q2013
Prepare RGs
Completed: 3Q2013
RGs Issued
Issued: 4Q2013
Employ Reg Guide PQD Analytical Limits
Elect to Perform PQD Testing
Track #1
• 65 plants which require no new models nor new LOCA calculations.
• Document compliance, revise UFSAR, and submit letter report to NRC.
• Approx. 50 AORs.
Completion: 4Q2015
Track #2
• 16 PWR plants currently using realistic models and require new analysis.
• 2 BWR/2 plants.
• Prepare LAR.
• Approx. 13 AORs.
Completion: 4Q2017
NRC Review
• Review Track #2 LARs.
Completed: 4Q2019
Track #3
• 23 PWR plants currently using Appendix K and require new analysis.
• 6 BWR/3 plants.
• Approx. 14 AORs.
Completion: 4Q2018
NRC Review
• Review Track #3 LARs.
Completed: 4Q2020
PQD Tests
• Perform PQD testing.
• Develop analytical limits.
Completion: 4Q2014
NRC Review
• Review analytical limits.
Completed: 4Q2015
Breakaway Tests
• Perform breakaway oxidation testing.
• Develop analytical limits.
Completion: 4Q2014
NRC Review
• Review analytical limits.
Completed: 4Q2016
Periodic Breakaway Tests
Periodic Breakaway Tests
Periodic Breakaway Tests
Periodic Breakaway Tests
Periodic Breakaway Tests
Periodic Breakaway Tests
Periodic Breakaway Tests
Cladding Hydrogen Uptake Models
• Collect hot-cell hydrogen measurements.
• Develop alloy-specific hydrogen uptake models.
• Approx. 9 models
Completed: 4Q2014
NRC Review
• Review vendors alloy-specific hydrogen models.
Completed: 4Q2015
LOCA Model Updates
• Vendors update LOCA models and methods.
• Approx. 12 models
Completed 4Q2014
NRC Review
• Review LOCA models and methods.
Completed: 4Q2016

Background of the 10 CFR 50.46c Proposed Rule and Related Activities

December 15, 2011

Tara Inverso
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Meeting Purpose

- Present the 10 CFR 50.46c proposed rule to ACRS
- Review the three associated draft regulatory guides
- Provide an overview of the related safety assessment/audit

Meeting Agenda

1. Background of 50.46c Rulemaking Activities
2. Overview of 50.46c Proposed Rule
3. Overview of Associated Regulatory Guidance
4. Overview of BWR/PWR Owners' Group Report
5. Overview of Safety Assessment
6. Proposed Implementation Schedule

Rulemaking Purpose

- Revise ECCS acceptance criteria to reflect recent research findings
- SECY-02-0057
  – Replace prescriptive analytical requirements with performance-based requirements
  – Expand applicability to all fuel designs and cladding materials
- Address concerns raised in two PRMs: PRM-50-71 and PRM-50-84

Public Interaction

- Advance Notice of Proposed Rulemaking Published
  - August 13, 2009 (74 FR 40765)
  - Requested specific comment on 12 issues/questions
- Public Workshop
  - April 28-29, 2010
- Public Meetings on Safety Assessment
  - August 12, 2010; December 2, 2010; March 3, 2011

Recent ACRS Interaction

- Research Findings – Regulatory Basis for 50.46c Rule
  - Presented RIL-0801 and NUREG/CR-6967 on December 2, 2008 (sub-committee) and December 4, 2008 (full committee)
  - “Mechanical Behavior of Ballooned and Ruptured Cladding” presented on June 23, 2011 (sub-committee) and July 13, 2011 (full committee)
- Draft regulatory guidance:
  - Presented to ACRS on May 10, 2011 (sub-committee) and June 8, 2011 (full committee)

Fuel Fragmentation, Relocation, and Dispersal

- Further research is necessary to understand fuel dispersal and its significance
- The staff recommends that the 50.46c rulemaking proceed to address the known embrittlement phenomenon
  - As written, the proposed rule satisfies all objectives/Commission direction

Rulemaking Schedule

- ACRS Meetings on Proposed Rule:
  - Sub-committee: December 15, 2011
  - Full committee: January 19, 2012

- Proposed Rule Due to the Executive Director for Operations:
  - February 29, 2012

Questions?

Tara Inverso, Project Manager

301-415-1024; tara.inverso@nrc.gov

Overview of the 10 CFR 50.46c Proposed Rule

December 15, 2011

Paul Clifford
Division of Safety Systems
Office of Nuclear Reactor Regulation

Agenda

- ECCS Design Function
- Structure of Performance-Based Rule
- Overview of 50.46c Rule Language

ECCS Design Function

- Emergency Core Cooling System consists of SSCs designed to replenish liquid inventory and maintain core temperatures at an acceptable level during and following a postulated LOCA.

Loss of Coolant Accident

Definition from 50.46(c)(1):

Loss-of-coolant accident (LOCA) means a hypothetical accident that would result from the loss of reactor coolant, at a rate in excess of the capability of the reactor coolant makeup system, from breaks in pipes in the reactor coolant pressure boundary up to and including a break equivalent in size to the double-ended rupture of the largest pipe in the reactor coolant system.

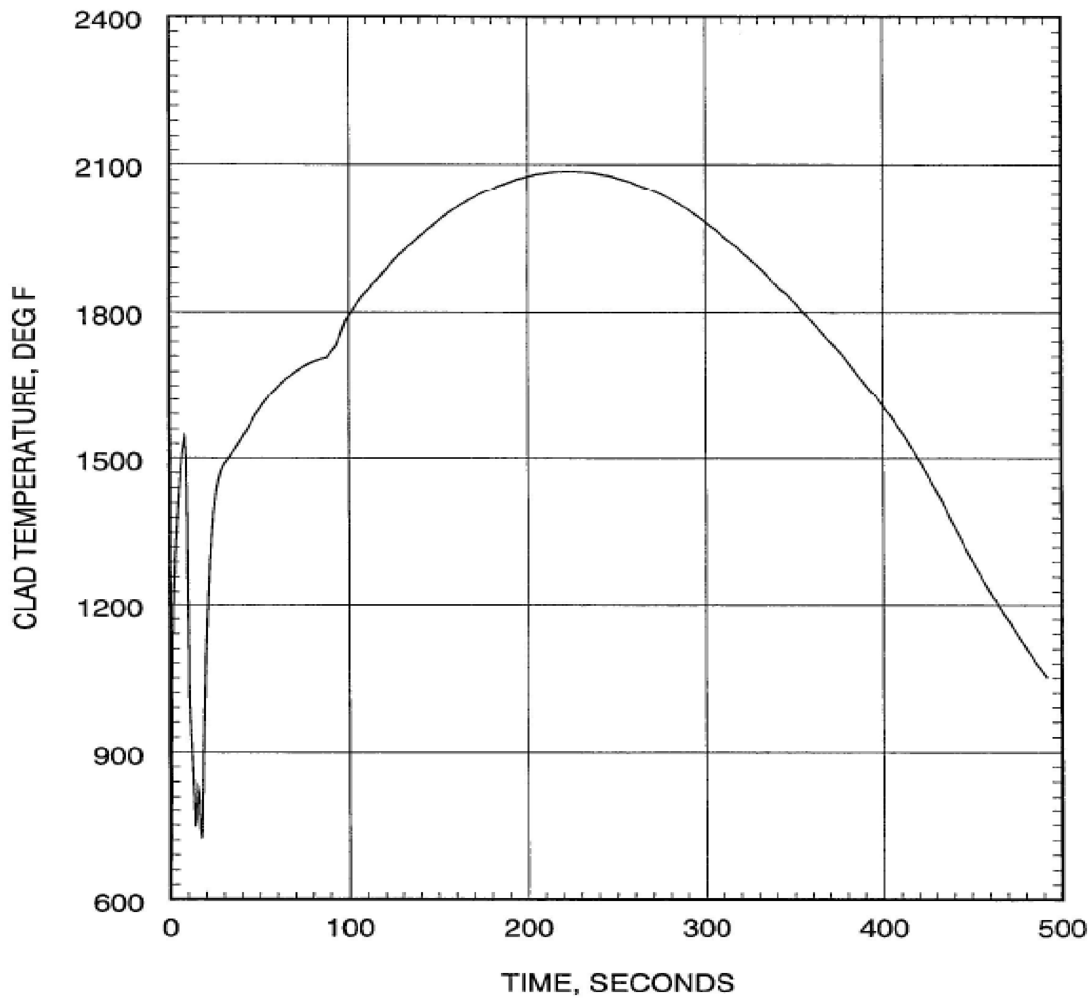
LOCA (cont.)

- As a result of a primary system piping break:
  - Loss of primary coolant inventory
  - Depressurization of primary pressure
  - Consequential heat up of fuel rods

- Initial rate of change in above parameters depends on break size and location.

LOCA (cont.)

PWR LBLOCA, Double Ended Guillotine At Pump Discharge



Rule Structure

Performance-based nature necessitated major restructuring of proposed 50.46c rule.

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Rule Structure (cont.)

50.46c ECCS Performance During LOCA

(a) Applicability
(b) Definitions
(c) Relationship to Other NRC Regulations
(d) ECCS Design
(e) [reserved]
(f) [reserved]
(g) Fuel System Design – (current designs)
(h) [reserved]
(i) [reserved]
(j) [reserved]
(k) Use of NRC Approved Fuel
(l) Authority to Impose Restrictions on Operation
(m) Reporting
(n) [reserved]
(o) Implementation

Rule Structure (cont.)

Emergency Core Cooling System:

1. Define **principal** performance objectives
   – Maintain acceptable core temperature during a LOCA.
   – Remove decay heat following a LOCA.

2. Define **principal** analytical requirements for ECCS performance demonstration

> > Dependent of Fuel Design < <

Rule Structure (cont.)

For <u>each</u> fuel design:

1. Define **specific** performance requirements and analytical limits which form the basis of "acceptable core temperature" based upon all established degradation mechanisms and unique features.
2. Define **specific** analytical requirements which impact the predicted performance of the fuel under LOCA conditions.

Rule Structure (cont.)

Current Fuel Designs:

- Based upon extensive empirical database, including recent findings from High Burnup LOCA Research Program, 50.46c defines specific performance and analytical requirements for current fuel designs.

New Fuel Designs:

- Additional research may be necessary to identify all degradation mechanisms and any unique features.
- New performance objectives, analytical limits, and analytical requirements would need to be established based upon this research.
- Several paragraphs reserved within 50.46c for future rulemaking on new fuel designs.

50.46c Rule Language

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Paragraph (a)

(a) ***Applicability***. The requirements of this section apply to the design of a light water nuclear power reactor (LWR), and to the following entities who design, construct or operate an LWR: each applicant for or holder of a construction permit under this part, each applicant for or holder of an operating license under this part (until the licensee has submitted the certification required under 10 CFR 50.82(a)(1) to the NRC), each applicant for or holder of a combined license under 10 CFR part 52, each applicant for a standard design certification (including the applicant for that design certification after the NRC has adopted a final design certification rule), each applicant for or holder of a standard design approval under 10 CFR part 52, and each applicant for or holder of a manufacturing license under 10 CFR part 52.

- Achieves rulemaking objective to expand applicability beyond “zircaloy or ZIRLO” to all LWRs
- Eliminates need for exemption requests for new zirconium alloys.

Paragraph (b)

(b) *Definitions*. As used in this section:

(1) Loss-of-coolant accident *(unchanged)*

(2) *Evaluation model* *(unchanged)*

(3) *Breakaway oxidation,* for zirconium-alloy cladding material, means the fuel cladding oxidation phenomenon in which weight gain rate deviates from normal kinetics. This change occurs with a rapid increase of hydrogen pickup during prolonged exposure to a high temperature steam environment, which promotes loss of cladding ductility.

- Defines new cladding embrittlement mechanism.

Paragraph (c)

(c) *Relationship to other NRC regulations.* The requirements of this section are in addition to any other requirements applicable to an emergency core cooling system (ECCS) set forth in this part. The analytical limits established in accordance with this section, with cooling performance calculated in accordance with an NRC approved evaluation model, are in implementation of the general requirements with respect to ECCS cooling performance design set forth in this part, including in particular Criterion 35 of appendix A of this part.

- Clarifies approval of evaluation model.

Paragraph (d)

(d) *Emergency core cooling system design.*

(1) *ECCS performance criteria.* Each LWR must be provided with an ECCS designed to satisfy the following performance requirements in the event of, and following, a postulated loss-of-coolant accident (LOCA). The demonstration of ECCS performance must comply with paragraph (d)(2) of this section:

(i) Core temperature during and following the LOCA event does not exceed the analytical limits for the fuel design used for ensuring acceptable performance as defined in this section.

(ii) The ECCS provides sufficient coolant so that decay heat will be removed for the extended period of time required by the long-lived radioactivity remaining in the core.

- Defines ECCS performance objectives.
  - Core temperature must remain below fuel-specific analytical limits.
  - Sufficient capability for long-term cooling.

Paragraph (d) (cont.)

(2) *ECCS performance demonstration*.

ECCS performance must be demonstrated using an evaluation model meeting the requirements of either paragraph (d)(2)(i) or (d)(2)(ii), paragraph (d)(2)(iii), and paragraph (d)(2)(iv), and satisfy the analytical requirements in paragraph (d)(2)(v) of this section. The evaluation model must be reviewed and approved by the NRC.

(i) *Realistic ECCS model.* A realistic model must include sufficient supporting justification to show that the analytical technique realistically describes the behavior of the reactor system during a loss-of-coolant accident. Comparisons to applicable experimental data must be made and uncertainties in the analysis method and inputs must be identified and assessed so that the uncertainty in the calculated results can be estimated. This uncertainty must be accounted for, so that when the calculated ECCS cooling performance is compared to the applicable specified and NRC-approved analytical limits there is a high level of probability that the limits would not be exceeded.

(ii) *Appendix K model*. Alternatively, an ECCS evaluation model may be developed in conformance with the required and acceptable features of appendix K ECCS Evaluation Models.

- Requires ECCS demonstration using approved evaluation model (either App.K or realistic).

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Paragraph (d) (cont.)

(iii) *Core geometry and coolant flow*. The ECCS evaluation model must address calculated changes in core geometry and must consider those factors that may alter localized coolant flow or inhibit delivery of coolant to the core.

- Requires factors which impact predicted core geometry and coolant flow be included in the evaluation model.
  - Fuel-specific factors defined in subsequent sections.

Paragraph (d) (cont.)

(iv) *LOCA analytical requirements*. ECCS performance must be demonstrated for a range of postulated loss-of-coolant accidents of different sizes, locations, and other properties, sufficient to provide assurance that the most severe postulated loss-of-coolant accidents have been identified. ECCS performance must be demonstrated for the accident, and the post-accident recovery and recirculation period.

- Clarifies demonstration during and following postulated LOCA.

Paragraph (d) (cont.)

(v) *Modeling requirements for fuel designs-uranium oxide or mixed uranium-plutonium oxide pellets within zirconium-alloy cladding*. If the reactor is fueled with uranium oxide or mixed uranium-plutonium oxide pellets within cylindrical zirconium-alloy cladding, then the ECCS evaluation model must address the fuel system modeling requirements in paragraph (g)(2) of this section.

- Pointer to analytical requirements for current fuel designs.

Paragraph (d) (cont.)

(3) ***Required documentation.***

(i)(A) (unchanged from Appendix K)

(B). (unchanged from Appendix K)

(ii). (unchanged from Appendix K)

(iii). (unchanged from Appendix K)

(iv). (unchanged from Appendix K)

(v). (unchanged from Appendix K)

(vi) For operating licenses issued under this part as of **[EFFECTIVE DATE OF RULE]**, required documentation of Table 1 must be submitted to demonstrate compliance by the date specified in Table 1.

- Specifies documentation requirements for Appendix K and realistic models.
- Pointer to implementation schedule.

Paragraph (g)

(g) *Fuel system designs: uranium oxide or mixed uranium-plutonium oxide pellets within cylindrical zirconium-alloy cladding.*

(1) *Fuel performance criteria.* Fuel consisting of uranium oxide or mixed uranium-plutonium oxide pellets within cylindrical zirconium-alloy cladding must be designed to meet the following requirements:

> (i) *Peak cladding temperature*. Except as provided in paragraph (g)(1)(ii) of this section, the calculated maximum fuel element cladding temperature shall not exceed 2200º F.

- Specifies performance requirements and analytical limits used to judge ECCS performance for current fuel designs.
- Research confirmed embrittlement above 2200 ºF.
- PCT limit also prevents runaway oxidation and high temperature failure.

Paragraph (g) (cont.)

(ii) *Cladding embrittlement*. Analytical limits on peak cladding temperature and integral time at temperature shall be established which correspond to the measured ductile-to-brittle transition for the zirconium-alloy cladding material based on a NRC-approved experimental technique. The calculated maximum fuel element temperature and time at elevated temperature shall not exceed the established analytical limits. The analytical limits must be approved by the NRC. If the peak cladding temperature, in conjunction with the integral time at temperature analytical limit, established to preserve cladding ductility is lower than the 2200º F limit specified in (g)(1)(i), then the lower temperature shall be used in place of the 2200º F limit.

- Maintains cladding ductility as performance objective.
- Captures research finding.
  - Hydrogen enhanced beta-layer embrittlement.
- RG provides acceptable analytical limits.
- RG provides acceptable experimental technique.

Paragraph (g) (cont.)

(iii) *Breakaway oxidation.* The total accumulated time that the cladding is predicted to remain above a temperature at which the zirconium-alloy has been shown to be susceptible to breakaway oxidation shall not be greater than a limit which corresponds to the measured onset of breakaway oxidation for the zirconium-alloy cladding material based on a NRC-approved experimental technique. The limit must be approved by the NRC.

- Maintains cladding ductility as performance objective.
- Captures research finding.
  - Breakaway oxidation (hydrogen uptake)
- RG provides acceptable experimental technique.

Paragraph (g) (cont.)

(iv) *Maximum hydrogen generation*. The calculated total amount of hydrogen generated from any chemical reaction of the fuel cladding with water or steam shall not exceed 0.01 times the hypothetical amount that would be generated if all of the metal in the cladding cylinders surrounding the fuel, excluding the cladding surrounding the plenum volume, were to react.

- Maintains existing requirement for combustible gas.

Paragraph (g) (cont.)

(v) *Long-term cooling*. An analytical limit on long-term peak cladding temperature shall be established which corresponds to the measured ductile-to-brittle transition for the zirconium-alloy cladding material based on a NRC-approved experimental technique. The calculated maximum fuel element temperature shall not exceed the established analytical limit. The analytical limit must be approved by the NRC.

- Maintains cladding ductility as performance objective.

Paragraph (g) (cont.)

(2) *Fuel system modeling requirements*. The evaluation model required by paragraph (d)(2) of this section must model the fuel system in accordance with the following requirement:

(i) If an oxygen source is present on the inside surfaces of the cladding at the onset of the LOCA, then the effects of oxygen diffusion from the cladding inside surfaces must be considered in the evaluation model.

- Specifies analytical requirements for current fuel designs.
- Captures research finding.
  - Oxygen ingress from cladding inside surface reduced time-at-temperature to nil ductility.

Paragraph (g) (cont.)

(ii) The thermal effects of crud and oxide layers that accumulate on the fuel cladding during plant operation must be evaluated. For purposes of this paragraph crud means any foreign substance deposited on the surface of fuel cladding prior to initiation of a LOCA.

- Achieves rulemaking objective to address petition for rulemaking.

Paragraph (k)

(k) *Use of NRC-approved fuel in reactor*. A licensee may not load fuel into a reactor, or operate the reactor, unless the licensee either determines that the fuel meets the requirements of paragraph (d) of this section, or complies with technical specifications governing lead test assemblies in its license.

- Clarifies requirement on use of NRC approved fuel designs for which specific ECCS performance requirements have been established.
- Recognizes importance of LTAs for collecting irradiated data to approve new fuel designs.

Paragraph (l)

(l) ***Authority to impose restrictions on operation.*** The Director of the Office of Nuclear Reactor Regulation (for licenses issued under 10 CFR part 50) or the Director of the Office of New Reactors (for licenses issued under 10 CFR part 52) may impose restrictions on reactor operation if it is found that the evaluations of ECCS cooling performance submitted are not consistent with the requirements of this section.

- Separates authority between NRR and NRO for imposing restrictions on operation.

Paragraph (m)

(m) *Reporting*.

(1) Each entity subject to the requirements of this section, which identifies any change to or error in an evaluation model or the application of such a model, or any operation inconsistent with the evaluation model or resulting noncompliance with the acceptance criteria in this section, shall comply with the requirements of this paragraph.

- Clarifies existing reporting requirements.

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Paragraph (m) (cont.)

(2) For the purposes of this section, a significant change or error is one which results in a calculated –

(i) Peak fuel cladding temperature different by more than 50 ^{0}F from the temperature calculated for the limiting transient using the last NRC-approved model, or is a cumulation of changes and errors such that the sum of the absolute magnitudes of the respective temperature changes is greater than 50 ^{0}F; or

(ii) Integral time at temperature different by more than 0.4 percent ECR from the oxidation calculated for the limiting transient using the last NRC-approved model, or is a cumulation of changes and errors such that the sum of the absolute magnitudes of the respective oxidation changes is greater than 0.4 percent ECR.

- Maintains threshold for significant change in calculated PCT at 50^{o}F.
- Adds a new threshold for significant change in calculated integral time at temperature of 0.4% ECR.

Paragraph (m) (cont.)

(3) Each holder of an operating license or combined license shall measure breakaway oxidation for each reload batch. The holder must report the results to the NRC annually i.e., anytime within each calendar year, in accordance with § 50.4 or § 52.3 of this chapter, and evaluate the results to determine if there is a failure to conform or a defect that must be reported in accordance with the requirements of 10 CFR part 21.

- Adds new reporting requirement for measured breakaway oxidation.
- Recognizes potential manufacturing-related changes in breakaway susceptibility.

Paragraph (o)

(o) ***Implementation.***

LATER

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Regulatory Guidance to support Emergency Core Coolant System rulemaking

December 15, 2011

Michelle Flanagan
Division of Systems Analysis
Office of Nuclear Regulatory Research

Background

- Presented to Materials, Metallurgy & Reactor Fuels Sub-committee on May 10, 2011
- Presented to ACRS Full Committee on June 8, 2011

  – ACRS letter to staff: “Draft Regulatory Guides DG-1261, DG-1262, DG-1263,” June 22, 2011 (ADAMS Accession No. ML11164A048)
  – Staff reply to ACRS: “Draft Regulatory Guides DG-1261, DG-1262 and DG-1263,” July 21, 2011 (ADAMS Accession No. ML111861706).

Background

- Rulemaking initiated to revise ECCS acceptance criteria to reflect new research findings
- The revisions are also intended to develop performance-based features of 10 CFR 50.46

- Therefore, 10 CFR 50.46c calls for:
  – Material-specific analytical limits which account for material-specific burnup effects
  – ECCS performance consistent with avoiding measured breakaway behavior
  – Periodic testing for breakaway behavior

Approach

These regulatory guides make it possible to revise 10 CFR 50.46c in a performance-based manner by:

- Providing a means of consistent, comparable generation of data to establish regulatory limits for peak cladding temperature (PCT) and oxidation
- Providing a means of consistent, comparable data generation to establish, and periodically confirm regulatory limits related to breakaway oxidation
- Providing a consistent means of using experimental data to establish regulatory limits
- Simplifying the staff's review process
- Reducing regulatory uncertainty, minimizing the costs associated with the implementation of the regulatory requirements proposed for 50.46c.

Approach

- DG-1261: Test procedure for measuring breakaway oxidation behavior and periodically confirming consistent behavior

- DG-1262: Testing procedure for measuring post-quench ductility using ring compression tests

- DG-1263: Developing analytical limits from measured data

Approach

Through stakeholder interaction and public comment, ensure that:

- the details and expectations of acceptable methods for measuring zirconium-based alloy behavior and developing limits are communicated effectively and completely
- measured behavior is expected to be repeatable within a laboratory
- measured behavior is expected to be repeatable between laboratories
- analytical limits will be developed consistently across fuel designs

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Context

Relationship to rule language

(1) *Fuel performance criteria.* Fuel consisting of uranium oxide or mixed uranium-plutonium oxide pellets within cylindrical zirconium-alloy cladding must be designed to meet the following requirements:

DG-1263

(i) …

(ii) *Cladding embrittlement.* **Analytical limits on peak cladding temperature and integral time at temperature shall be established** which correspond to the measured ductile-to brittle transition for the zirconium-alloy cladding material based on a **NRC-approved experimental technique**. The calculated maximum fuel element temperature and time at elevated temperature shall not exceed the established analytical limits. The analytical limits must be approved by the NRC. If the peak cladding temperature, in conjunction with the integral time at temperature analytical limit, established to preserve cladding ductility is lower than the 2200º F limit specified in (g)(1)(i), then the lower temperature shall be used in place of the 2200º F limit.

(iii) …

DG-1262

Context

Relationship to rule language

(1) *Fuel performance criteria.* Fuel consisting of uranium oxide or mixed uranium-plutonium oxide pellets within cylindrical zirconium-alloy cladding must be designed to meet the following requirements:

(i) *….*

(ii)…

(iii) Breakaway oxidation. The total accumulated time that the cladding is predicted to remain above a temperature at which the zirconium-alloy has been shown to be susceptible to breakaway oxidation **shall not be greater than a limit** which corresponds to the measured onset of breakaway oxidation for the zirconium-alloy cladding material based on a **NRC-approved experimental technique**. The limit must be approved by the NRC.

DG-1263

DG-1261

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Schedule

- Draft guides will be issued for public comment at the same time as the proposed rule is issued for public comment
- Draft guides will then follow standard revision and review process

Overview of Industry Margin Assessment

Kurt Flaig - PWROG Representative
Tom Eichenberg - BWROG Representative

ACRS Subcommittee Meeting
December 15, 2011

Agenda

- Objectives
- Background
- Overview of Margin Assessments
- Conclusion

Objectives

- Provide Overview of Industry Assessment
- Show Operating Plants Have Margin with Respect to Research Findings

Background

- NRC Research Results Regarding Cladding Embrittlement (NUREG/CR-6967)
- NRC Staff Requested an Assessment of Research Results with Respect to the Operating Fleet
- Industry Proposed a Vehicle Providing Relevant Information to NRC
- NEI Provided the Industry Assessment Reports

Assessment Overview

- Survey Approach
- Identify Evaluation Criteria Based on Research
- Identify Conservatisms and Margin
- Plant Grouping Approach

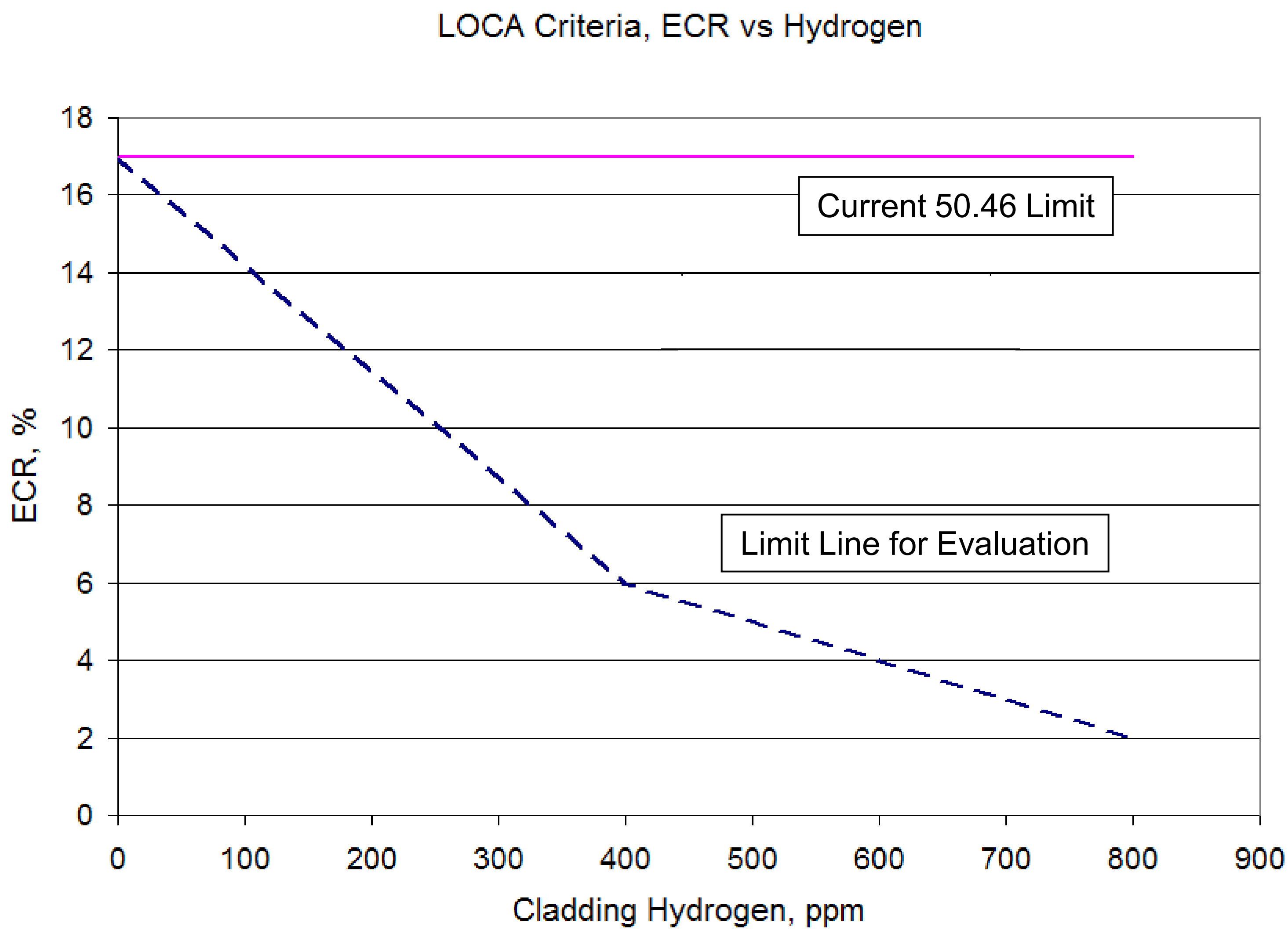
Survey Approach

- Starting Point
  - Analyses of Record
- Establish Initial Margins
- Determine Creditable Conservatisms as Necessary

Evaluation Basis

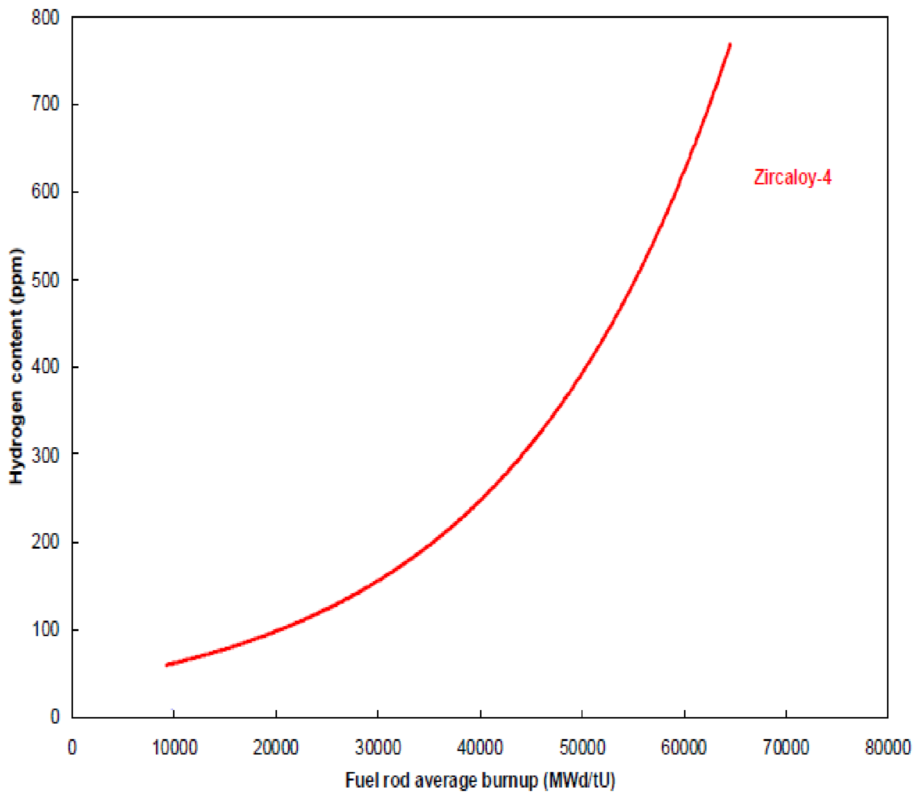
- Embrittlement Limit
  - Hydrogen uptake models
- Double-Sided Equivalent Clad Reacted (ECR)
  - Burst rods accounted for by current evaluation models
  - Accounted for inside ECR contribution
- Breakaway Oxidation
  - Time above 800ºC

Embrittlement Criteria



Hydrogen Uptake

- Alloy-Specific Models presented in Assessment Report
  - Best estimate hydrogen vs. exposure conversion
    - Allowable ECR based on initial hydrogen concentration



Double-Sided ECR Contribution

- Rod Exposures Above 45 GWd/MTU

Breakaway Oxidation

- 5000 Seconds Above 800ºC
  - Based on ANL and industry testing

Examples of Applied Conservatisms

- Appendix K vs. Best-Estimate Methodology
- Approved Best-Estimate Methodology Improvements
- Baker-Just vs. Cathcart-Pawel
- Reload Power History
- Peak Cladding Temperature Dependent Brittle-Ductile Transition
- ANS-1979 Decay Heat Plus 2σ Uncertainty
- Thermal-Mechanical Limits to Operation
    - LHGR limit

Plant Grouping Factors

- Large vs. Small Break Limited
- Plant Design/ECCS Features
- Type of Cladding Material
- Type of Evaluation Methodology
- Conservatism Credits

PWR LBLOCA Groupings

- Group 1 Contains 41 Units
  - No adjustments required to meet limits
- Group 2 Contains 2 Units
  - Approved best-estimate methodology improvements
    - **ECR reduced ~50%**
- Group 3 Contains 6 Units
  - Appendix K to a best-estimate methodology
    - **ECR reduced ~60%**
- Group 4 Contains 4 Units
  - Improved statistics in ASTRUM
    - **ECR reduced ~ 40%**

PWR LBLOCA Groupings (Continued)

- Group 5 Contains 1 Unit
  - Explicit burnup study
    - **ECR reduced ~ 50%**
- Group 6 Contains 7 Units
  - Approved best-estimate methodology improvements
  - Improved ASTRUM statistics
    - **ECR reduced ~ 60%**
  - Increased allowable ECR criteria
- Group 7 Contains 8 Units
  - Baker-Just to Cathcart-Pawel
  - Reload power histories
    - **ECR reduced ~40%**

PWR SBLOCA Groupings

- Group 1 Contains 59 Units
  - No adjustments required to meet limits
- Group 2 Contains 5 Units
  - ANS-1979 decay heat plus 2σ uncertainty
    - **ECR reduced ~ 90%**
- Group 3 Contains 5 Units
  - Baker-Just to Cathcart-Pawel
  - Reload power histories
    - **ECR reduced ~30%**

BWR Groupings

- Group “2” Contains 2 Units
  - BWR/2 designs
  - Baker-Just to Cathcart-Pawel
  - Thermal-mechanical operating limits
    - **ECR reduced ~ 20%**
- Group “3” Contains 6 Units
  - BWR/3 designs
  - Thermal-mechanical operating limits
    - **ECR reduced ~ 95%**
- Groups “4”, “4a”, “5”, and “6” Contain 27 Units
  - BWR/4, 5, & 6 designs
  - No adjustments required to meet limits

Margin to Proposed Criteria

- Embrittlement
  - 41 of 69 PWR LBLOCA needed no adjustments
  - 59 of 69 PWR SBLOCA needed no adjustments
  - 27 of 35 BWR’s needed no adjustments
  - Remaining plants took credit for various conservatisms
- Breakaway Oxidation
  - No adjustments needed
- All Operating Plants Show Margin
  - With respect to research findings

Conclusion

- Industry Provided Margin Assessment Reports Encompassing the Operating Fleet
- All Operating Plants Show Margin with Respect to Research Findings

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ECCS Performance Safety Assessment

December 15, 2011

Paul Clifford
Division of Safety Systems
Office of Nuclear Reactor Regulation

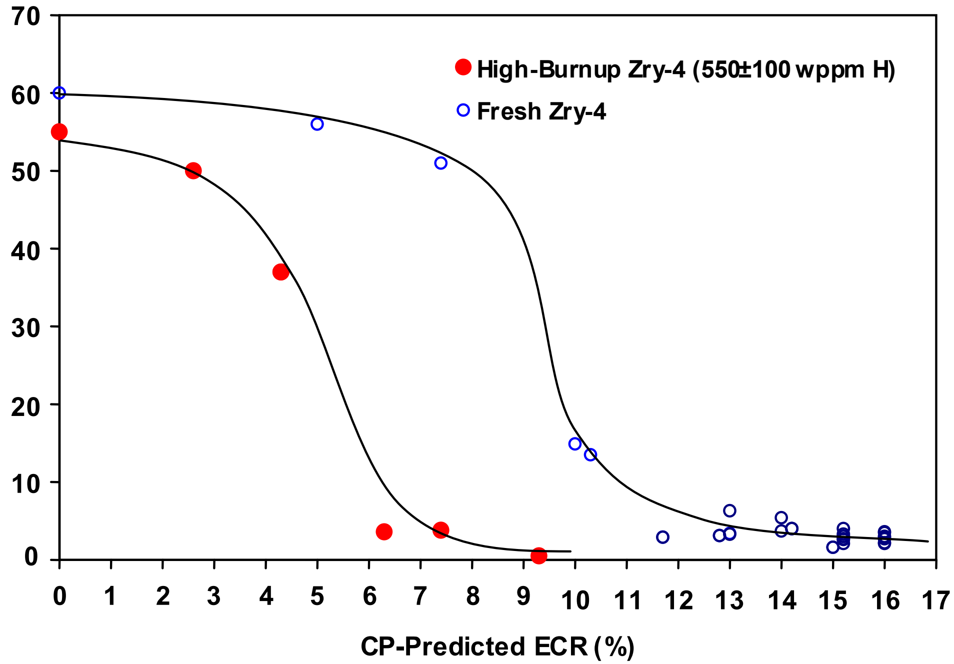
Agenda

1. Research Findings
2. Initial Safety Assessment
3. Draft Generic Letter
4. ECCS Performance Assessment

Research Findings

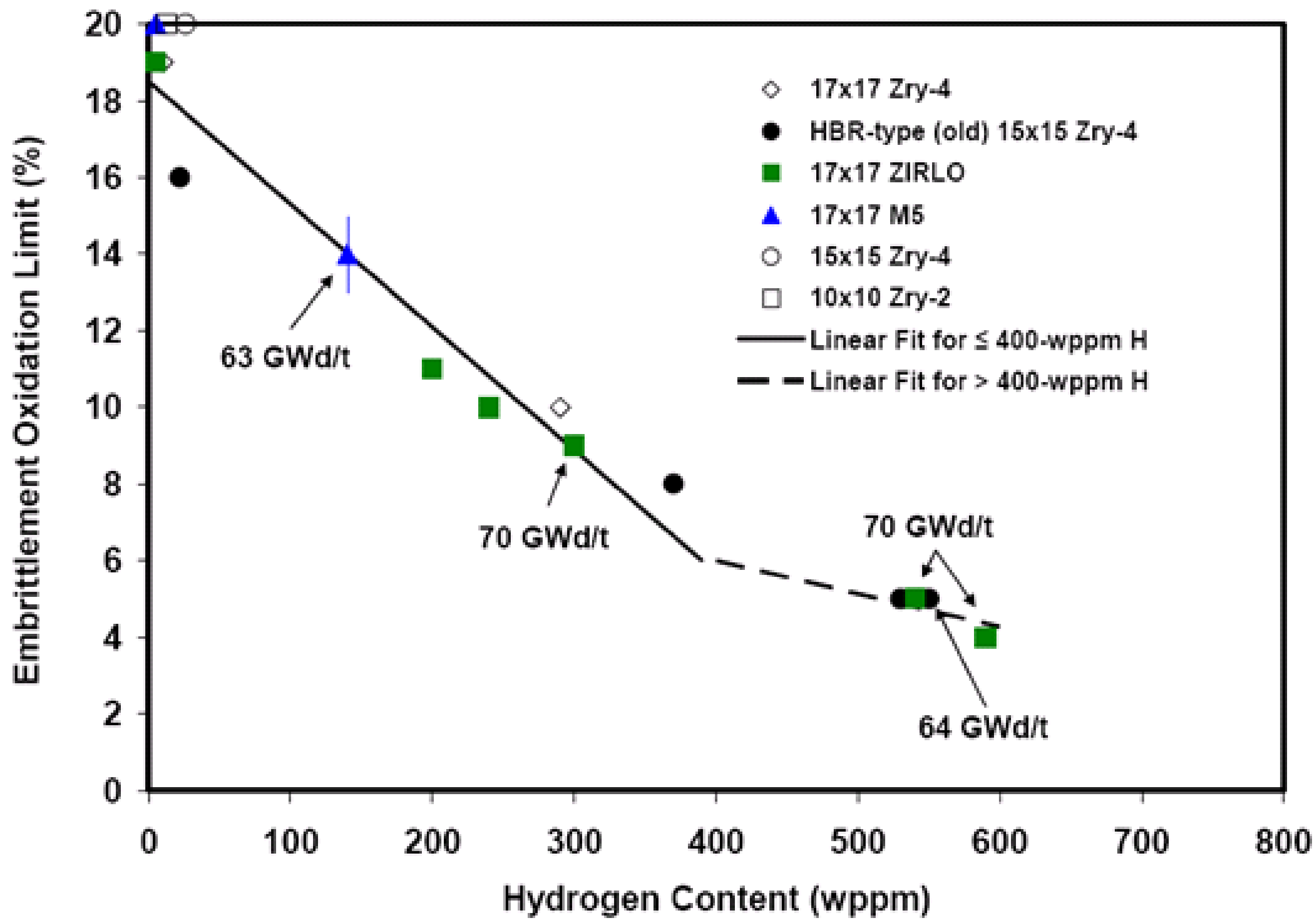
New Embrittlement Mechanisms:

1. Hydrogen-enhanced beta layer embrittlement.
   - Pre-transient cladding hydrogen content impacts rate of embrittlement.
   - Hydrogen absorption sensitive to alloy composition, fabrication, and in-reactor service.



Research Findings (cont.)

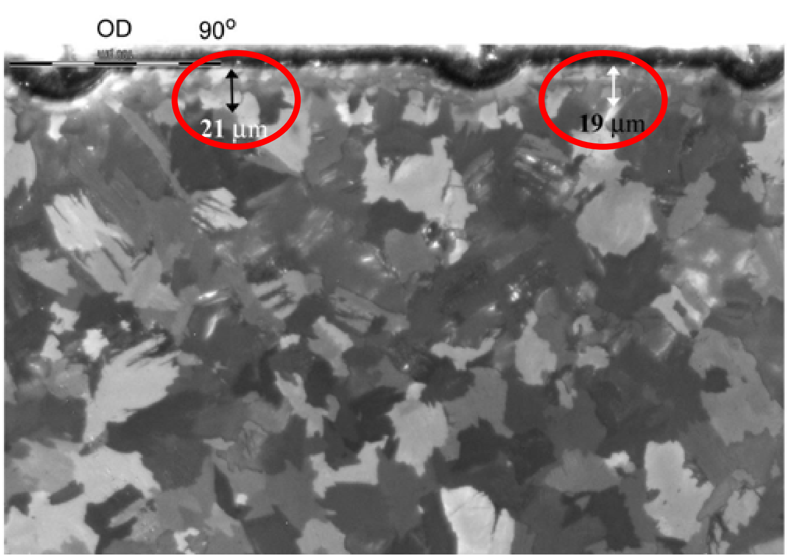
- Allowable time-at-temperature reduced from current regulatory requirement (17%ECR).

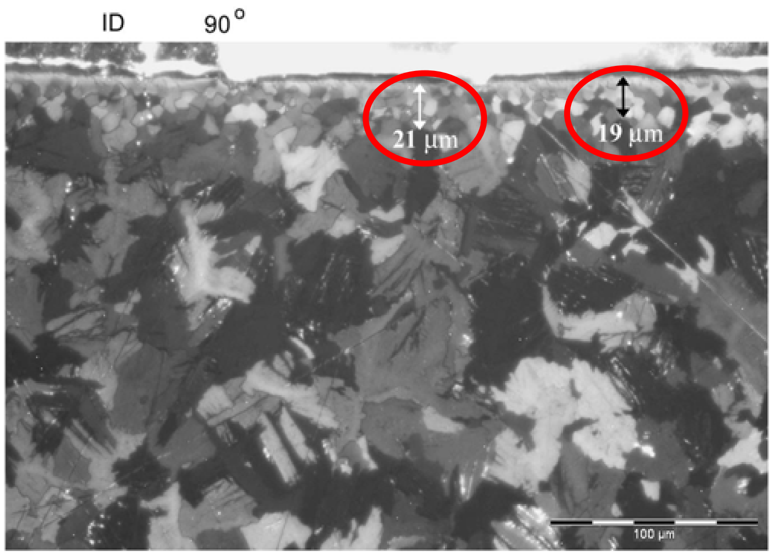


Research Findings (cont.)

New Embrittlement Mechanisms:

2. Cladding ID oxygen diffusion expedites embrittlement.
   - Oxygen ingress from cladding ID reduces allowable time-at-temperature to nil ductility.
   - ID oxygen source sensitive to burnup, power history, and fuel rod design.





Micrograph images of Halden LOCA test specimens of outer cladding surface (left) and inner cladding surface (right) indicating oxygen-stabilized zirconium layers on both surfaces.

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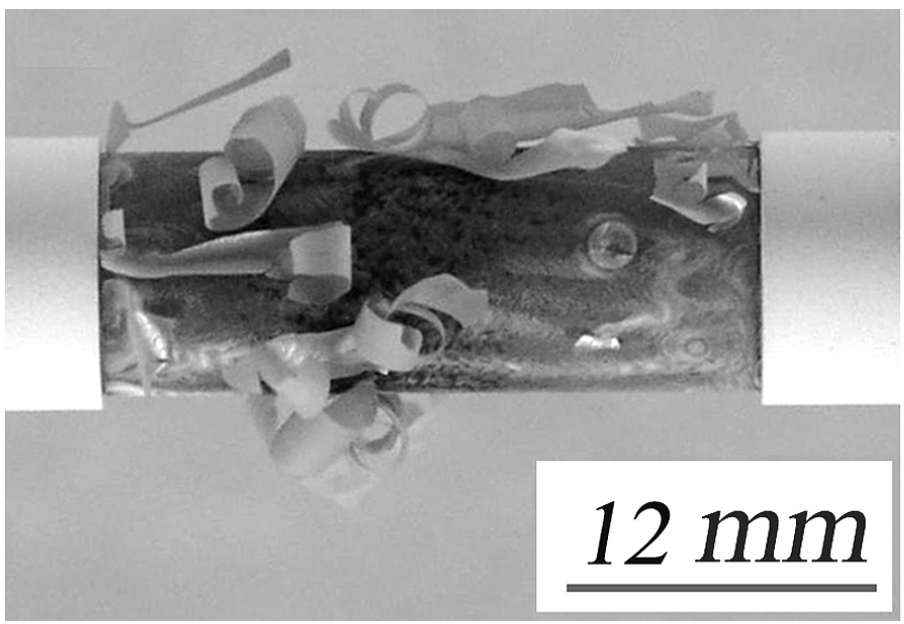
Research Findings (cont.)

New Embrittlement Mechanisms

3. Degradation of protective oxide layer (breakaway oxidation).
   - Breakaway oxidation results in cladding embrittlement due to hydrogen uptake.
   - Susceptibility to breakaway sensitive to alloy composition and fabrication.



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Initial Safety Assessment

- In response to RIL-0801, NRR completed initial safety assessment (July 2008)
  - Due to measured performance, realistic rod power history, and current analytical conservatisms, sufficient safety margin exists for operating reactors.
  - No imminent safety risk. Proceed with rulemaking.
  - Additional research needs:
    - PQD measurements at intermediate hydrogen levels.
    - Breakaway measurements on transient temperature profiles.
    - Treatment of fuel rod burst region.

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Generic Letter

- Recognizing that finalization and implementation of the new ECCS requirements would take several years, the staff decided that a more detailed safety assessment was necessary
- To obtain the necessary plant-specific information, the staff developed a draft GL entitled, "Potential Embrittlement of Fuel Rods During Postulated Loss-of-Coolant Accidents."

Generic Letter (cont.)

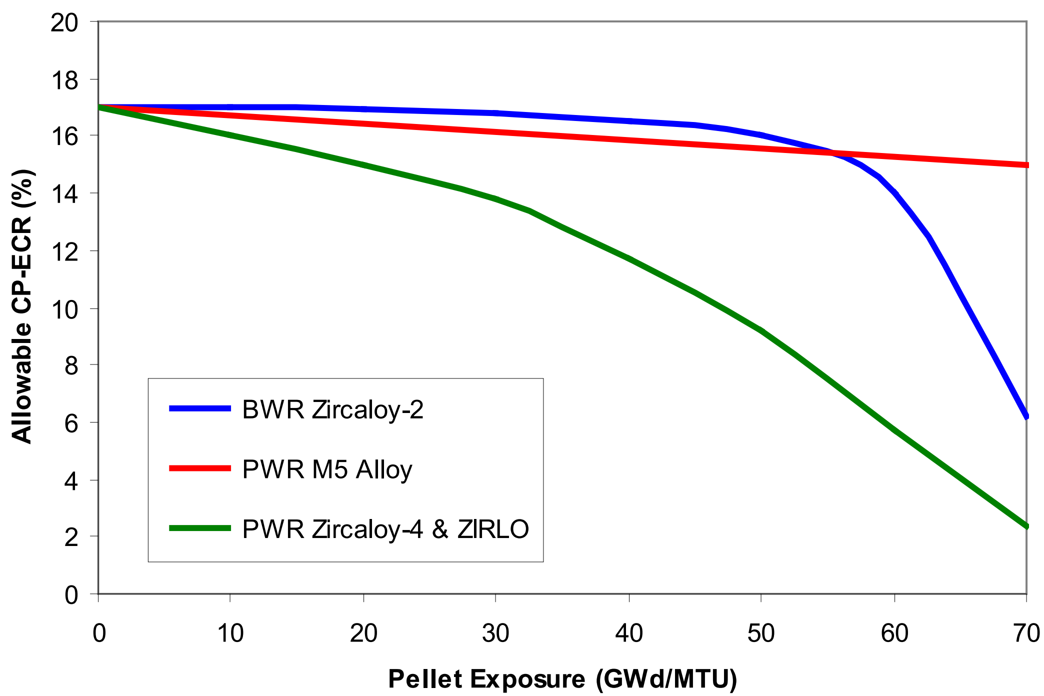
- Industry volunteered to provide requested information via PWROG and BWROG reports.
- Based upon the information provided OG reports and the information collected during the staff audits of the Westinghouse, AREVA, and GEH engineering calculations, the staff concludes that sufficient plant-specific information has been documented to complete the safety assessment.
- Therefore, no further regulatory action to request information is required and the draft GL need not be issued.

ECCS Performance Assessment

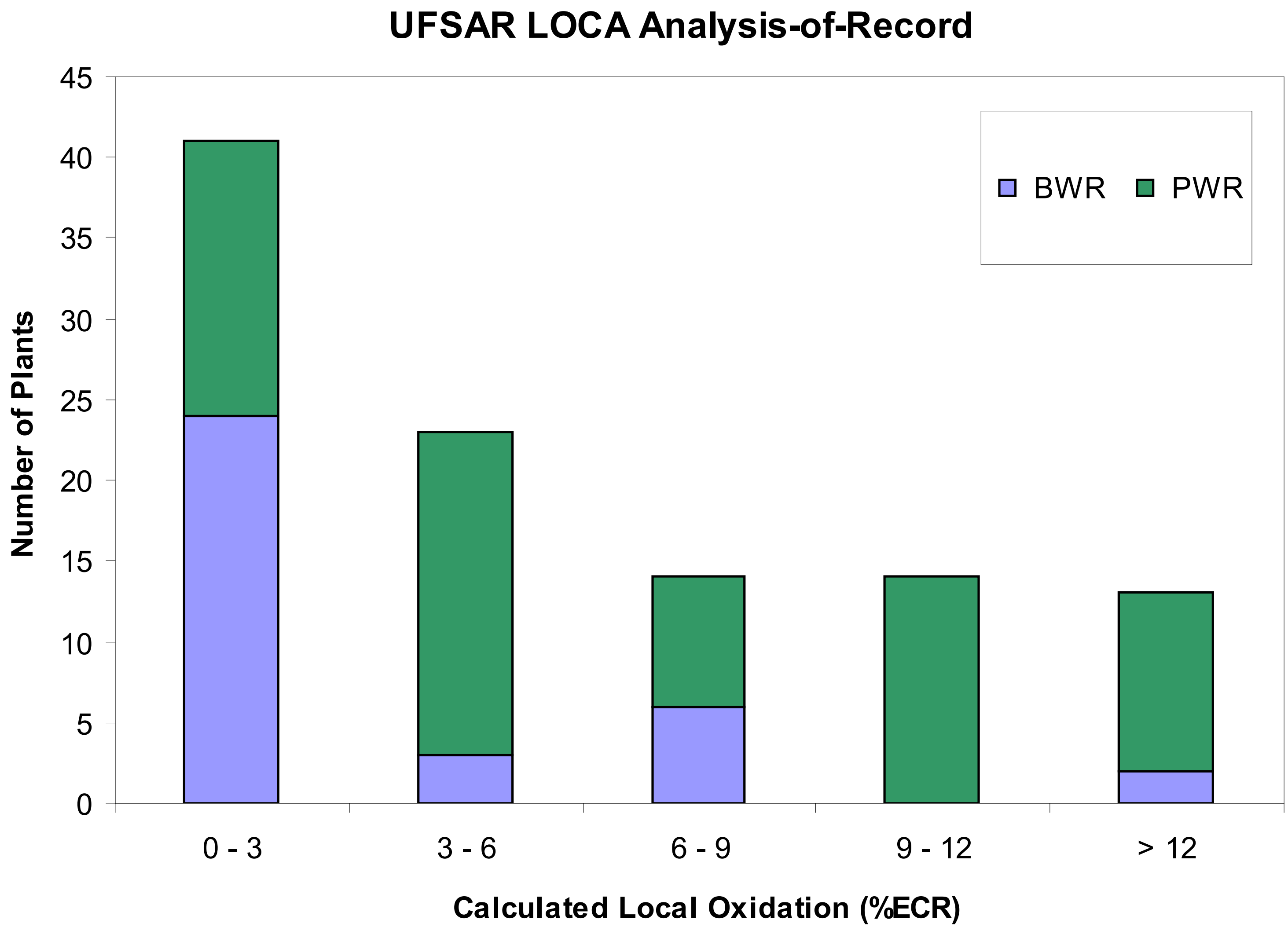
Draft GL Groundrules

Revised Analytical Limits:

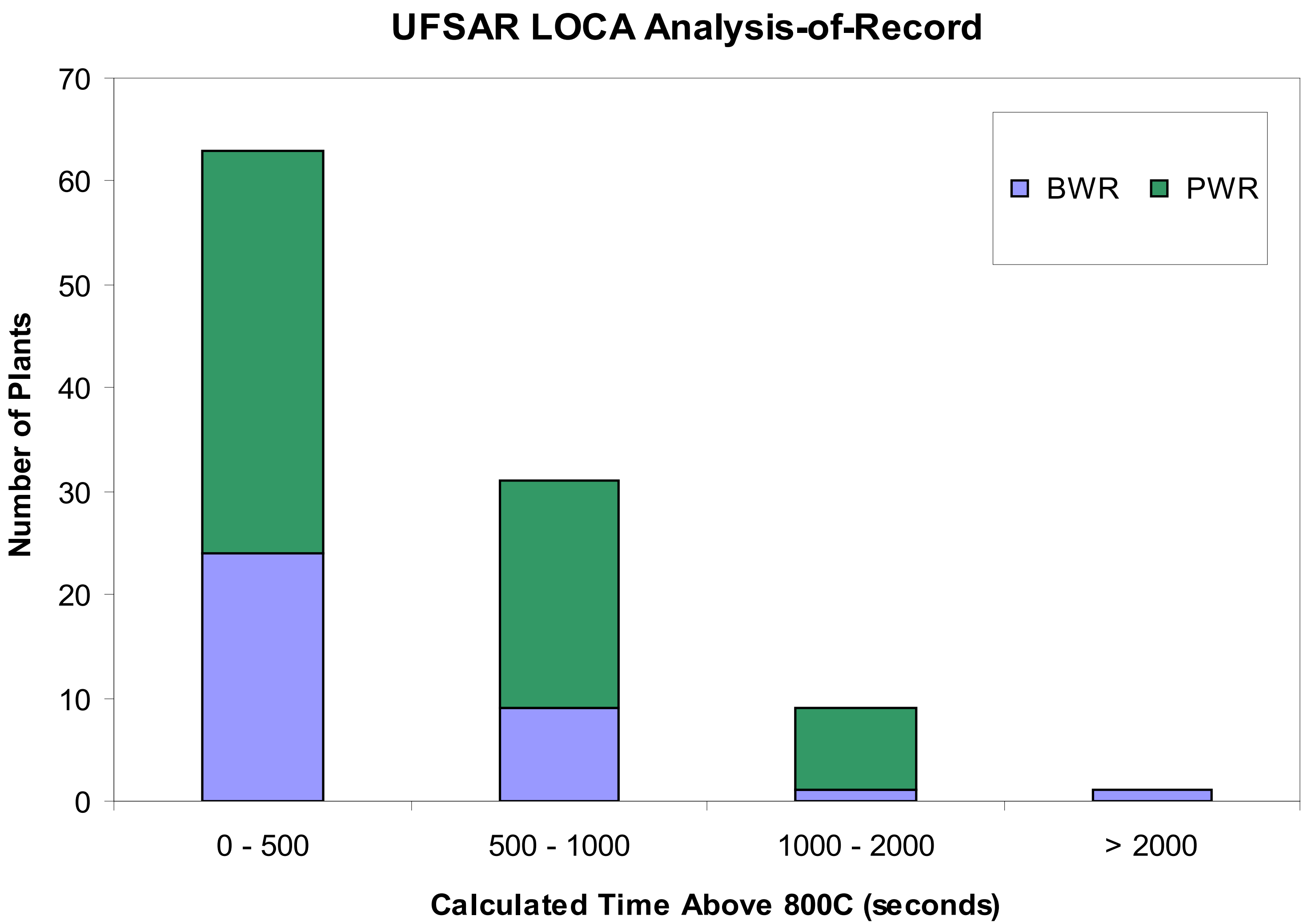
- Alloy-specific PQD analytical limit.
- Cladding ID oxygen ingress $\geq$ 45 GWd/MTU.
- Alloy-specific breakaway oxidation (time above 800^{o}C).



UFSAR AOR Results - MLO



UFSAR AOR Results – Breakaway



Post Quench Ductility

Revised PQD Analytical Limits:

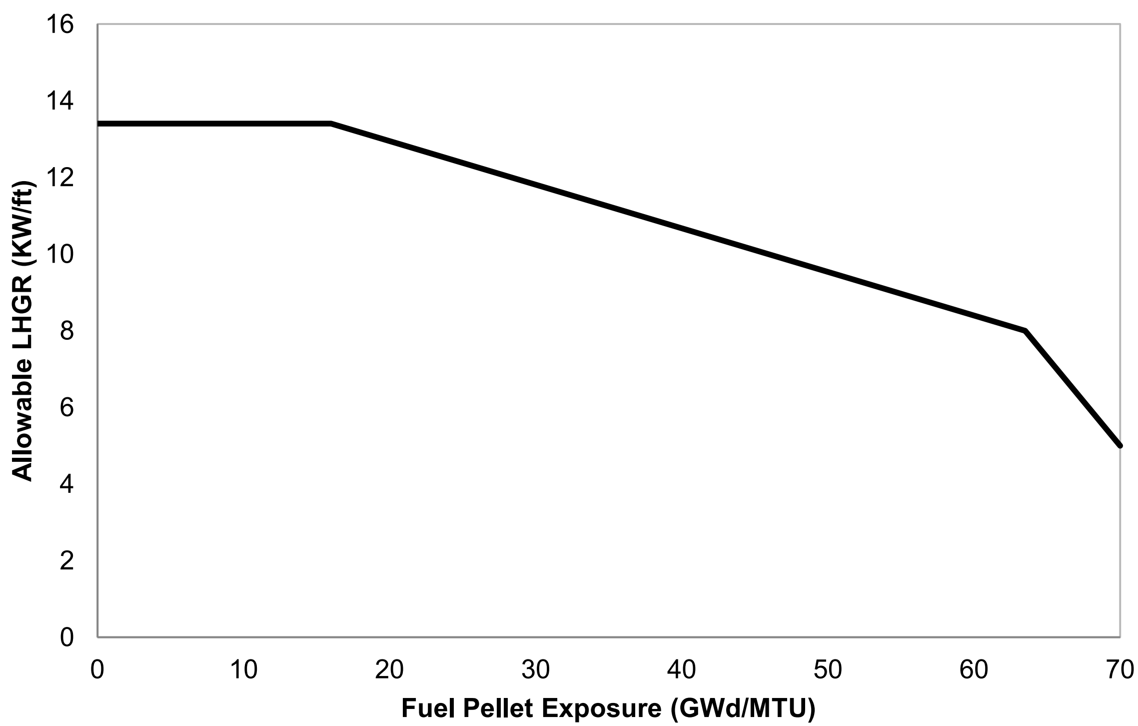
- 65 of 104 plants (63% of entire operating fleet) needed no adjustment or new calculations.
  - 27 of 35 BWRs (77% of BWR fleet)
  - 38 of 69 PWRs (55% of PWR fleet).

- All 104 plants continue to satisfy 2200^{o}F PCT criteria.

Post Quench Ductility (cont.)

Revised PQD Analytical Limits:

- 8 BWRs performed new LOCA calculations which credit COLR Thermal-Mechanical Operating Limits (TMOL) reduced rod power at higher burnup to satisfy new analytical limits.
- Approved models with no analytical adjustments.



Post Quench Ductility (cont.)

Revised PQD Analytical Limits:

- 31 PWRs either performed new LOCA calculations or identified credits to satisfy new analytical limits.
  - 9 PWRs performed new LOCA calculations which credit diminished fuel rod power at higher burnup.
  - 11 PWRs credit transition to improved evaluation models (e.g., ASTRUM LBLOCA or ANS 1979+2σ decay heat SBLOCA).
  - 4 PWRs credit improved statistics in ASTRUM methods.
  - 7 PWRs credited multiple items.

- All of the calculations were performed and documented in accordance with the fuel vendor’s 10 CFR 50 Appendix B quality assurance program.

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Breakaway Oxidation

Measured Breakaway Time:

- All plants exhibit margin to breakaway.
- 103 of 104 plants predict a time duration above 800°C of less than 2,000 seconds.

Alloy	Measured Breakaway Time
Zircaloy-2	>5,000 seconds
Zircaloy-4	5,000 seconds
ZIRLO™	3,500 seconds
M5	>5,000 seconds

- New requirement prevents introduction of susceptible cladding material like old E110.

Staff Audit

NRC staff audited Westinghouse, AREVA, and GEH calculations supporting OG reports.

- Confirmed that the revised PQD and breakaway analytical limits were in accordance with the research findings and that alloy-specific corrosion and hydrogen uptake models were accurate and supported by data.
- Evaluated the quantification, justification, and application of analytical credits.
- Reviewed a sampling of the new LOCA calculations and identified any changes to existing, approved models and methods.
- Compiled plant-specific data and evaluated each individual plant with respect to margin to the revised analytical limits.

ECCS Margin Database

ECCS Margin Database documents plant-specific information:

- Fuel vendor
- Fuel rod cladding alloy
- Evaluation model
- AOR results (calculated PCT, MLO, and time above 800°C)
- Plant grouping
- Margin to PQD analytical limit
- Margin to breakaway oxidation analytical limit
- Credited analytical adjustment(s)

Existing Commercial Fleet

- ECCS performance safety assessment confirms and documents, on a plant-specific basis, the continued safe operation of the U.S. commercial nuclear fleet.
- Future operation of Watts Bar Unit 2 and Bellefonte Units 1 and 2 expected to have sufficient margin to PQD and breakaway limits.
- Improved, corrosion resistant zirconium alloys being developed and implemented.

Certified Reactor Designs

- Advanced reactor designs include enhanced ECCS performance characteristics.
- Certified designs have significant margin relative to research data.

Design	PCT (ºF)	ECR (%)
ESBWR	No uncovery or heatup	
AP1000	1837	2.25
EPR	1695	1.53
US-APWR	1766	3.70

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Future Confirmation

- Planned changes which may impact margin assessment and involve License Amendment Requests:
  - Power uprate.
  - Major plant modifications.
  - New fuel design or design limits.
  - New LOCA methods.
- Unplanned changes which may impact margin assessment would be captured via existing 10CFR50.46(a)(3) reporting requirements.
  - Any change to or error discovered in evaluation model requires NRC notification.
  - Either 30 day (significant) or annual reporting requirement.

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Future Confirmation (cont.)

The staff will perform the following actions to confirm plant safety in the interim until the revised rule (10 CFR 50.46c) is implemented.

1. On an annual basis, the staff will update the ECCS Margin Database using the annual licensee 50.46(a)(3) reports .
2. On a continuous basis, the staff will scrutinize all 30-day significant 50.46(a)(3) reports to confirm existing margin assessment.
3. On a continuous basis, the staff will scrutinize any License Amendment Request which necessitates a change to the LOCA analysis-of-record and may impact the existing margin assessment .
4. As part of the annual vendor/NRC fuel update meetings, the staff will confirm that all changes which may impact the existing margin assessment have been identified and discuss future LARs which may impact the LOCA analysis-of-record.

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Conclusions

1. Research findings necessitate new ECCS requirements.
2. Majority of plants needed no new calculations or adjustments to show positive margin to the research data.
3. ECCS margin database confirms and documents, on a plant-specific basis, the continued safe operation of the U.S. commercial nuclear fleet.
4. NRC staff will continue to confirm plant safety until new regulations have been implemented.

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Implementation of 10 CFR 50.46c

December 15, 2011

Paul Clifford
Division of Safety Systems
Office of Nuclear Reactor Regulation

Agenda

1. Work Scope
2. Strategy
3. Implementation – Existing Plants
4. Implementation – New Plants

Work Scope

Industry:

1. Develop alloy-specific hydrogen uptake models.
2. Update LOCA models.
3. Establish PQD analytical limits.
4. Establish breakaway oxidation analytical limits.
5. Perform plant-specific LOCA analyses.
6. Prepare LARs.
7. Revise UFSARs.
8. Ongoing breakaway tests.

NRC:

1. Review alloy-specific hydrogen uptake models.
2. Review LOCA models.
3. Review breakaway test results
4. Review PQD and breakaway analytical limits.
5. Review LARs.

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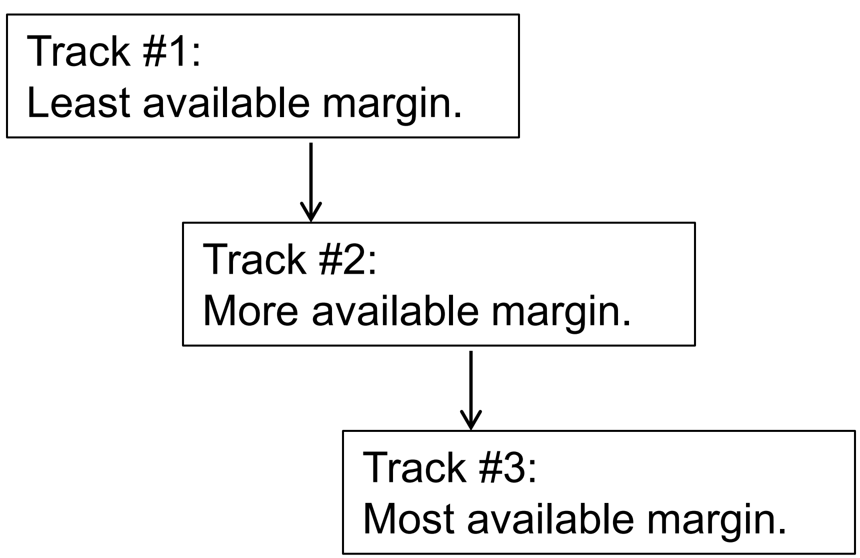
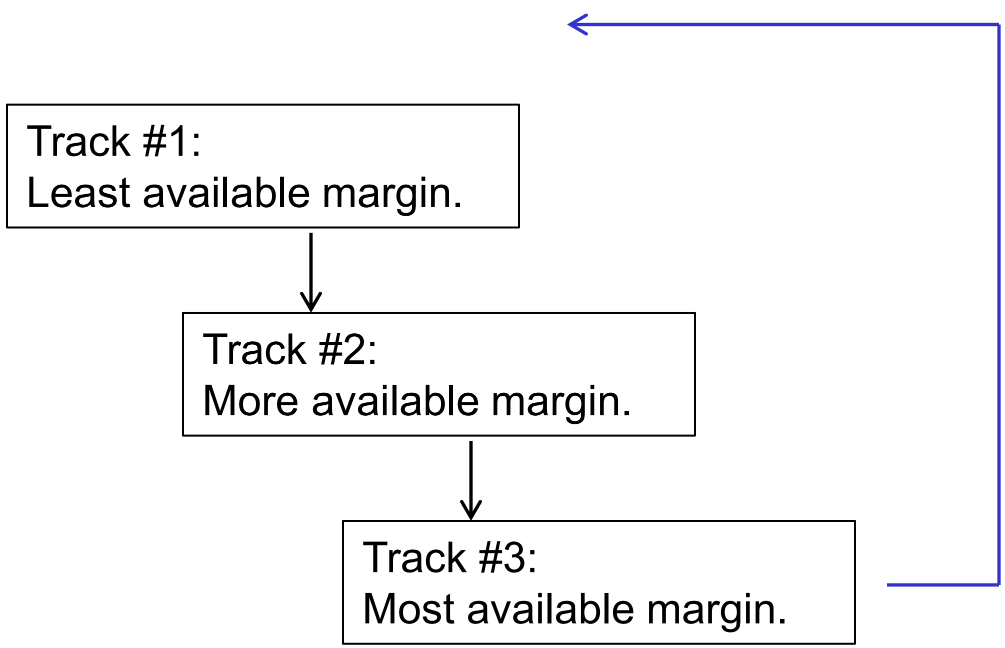
Strategy

- Based upon ANPR comments which identified work-force limitations to complete parallel analyses, a staged implementation plan would be the most effective and efficient way to implement 50.46c.
- Plants with the least available safety margin would be required to be in compliance earliest.



Strategy (cont.)

- Recognizing that (1) plants with the least amount of safety margin are likely to require the most effort and calendar time to document compliance and (2) a substantial number of plants do not require new LOCA analyses, the implementation plan was revised.



Strategy (cont.)

- Implementation plan designed to achieve the following objectives:
  1. Expedite implementation to as many plants as soon as possible,
  2. Prioritize implementation on plants with less inherent safety margin, and
  3. Balance work load.

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Implementation – Existing Fleet

Implementation Track	Basis	Anticipated Level of Effort	Number of Plants		Compliance Demonstration
			BWR	PWR	
1	All plants which satisfy new requirements without new analyses or model revisions.	Low	27	38	No later than 24 months from effective date of rule
2	PWR plants using realistic LBLOCA models requiring new analyses. BWR/2 plants.	Medium	2	14	No later than 48 months from effective date of rule
3	PWR plants using Appendix K LB and SB models requiring new analyses. BWR/3 plants.	Medium - High	6	17	No later than 60 months from effective date of rule

Paragraph (o)

(o) *Implementation*

Reactors under Part 50:

- Construction permits issued after the effective date of the rule must comply with the conditions of the rule.
- Operating licenses issued based on construction permits in effect as of the effective date of the rule must comply with the conditions of the rule no later than the date set forth in Table 1 of the rule.
- Operating licenses issued prior to the effective date of the rule must comply with the conditions of the rule no later than the date set forth in Table 1 of the rule.
- Operating licenses issued after the effective date of the rule must comply with the conditions of the rule.

Paragraph (o)

(o) *Implementation.*

Reactors under Part 52:

- All applications docketed after the effective date of the rule must comply with the conditions of the rule prior to approval.
- Standard design renewals after the effective date of the rule must comply with the conditions of the rule prior to approval.
- Standard design applications pending at effective date of the rule must comply with the conditions of the rule when renewal is submitted.
- Combined licenses docketed after the effective date of the rule must comply with the conditions of the rule.
- Combined licenses docketed or issued prior to the effective date of the rule must comply with the conditions of 50.46 until completion of the refueling outage after the initial fuel load, at which time they must comply with the conditions of this rule.

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Implementation Flow Chart


1Q2011
2Q2011
3Q2011
4Q2011
1Q2012
2Q2012
3Q2012
4Q2012
1Q2013
2Q2013
3Q2013
4Q2013
1Q2014
2Q2014
3Q2014
4Q2014
1Q2015
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3Q2017
4Q2017
1Q2018
2Q2018
3Q2018
4Q2018
1Q2019
2Q2019
3Q2019
4Q2019
1Q2020
2Q2020
3Q2020
NEI/Owners Group ECCS Margin Assessment
Done
Staff Audit & Safety Assessment
Completed: 3Q2011
10CFR50.46c Proposed Rule to EDO
Completed: 1Q2012
Draft RG Analytical Limits
Done
Draft RGs Test Procedures
Done
Round Robin
(Completed 4Q2012)
10CFR50.46c Proposed Rule Issued
Issued: 3Q2012
Public Comment Period
75 day comment period.
Ends: 1Q2013
Public Comment Period
75 day comment period.
Ends: 1Q2013
Public Comment Period
75 day comment period.
Ends: 1Q2013
Prepare Final Rule
Completed: 3Q2013
Prepare RG
Completed: 3Q2013
Prepare RGs
Completed: 3Q2013
10CFR50.46c Final Rule Issued
Issued: 4Q2013
RG Issued
Issued: 4Q2013
RGs Issued
Issued: 4Q2013
Cladding Hydrogen Uptake Models
Collect hot-cell hydrogen measurements.
Develop alloy-specific hydrogen uptake models.
Approx. 9 models
Completed: 4Q2014
LOCA Model Updates
Vendors update LOCA models and methods.
Approx. 12 models
Completed 4Q2014
Employ Reg Guide PQD Analytical Limits
Elect to Perform PQD Testing
Track #1
65 plants which require no new models nor new LOCA calculations.
Document compliance, revise UFSAR, and submit letter report to NRC.
Approx. 50 AORs.
Completion: 4Q2015
PQD Tests
Perform PQD testing.
Develop analytical limit.
Completion: 4Q2014
Breakaway Tests
Perform breakaway oxidation testing.
Develop analytical limits.
Completion: 4Q2014
NRC Review
Review analytical limits.
Completed: 4Q2015
NRC Review
Review analytical limits.
Completed: 4Q2016
NRC Review
Review vendors alloy-specific hydrogen models.
Completed: 4Q2015
NRC Review
Review LOCA models and methods.
Completed: 4Q2016
Track #2
16 PWR plants currently using realistic models and require new analysis.
2 BWR/2 plants.
Prepare LAR.
Approx. 13 AORs.
Completion: 4Q2017
Track #3
23 PWR plants currently using Appendix K and require new analysis.
6 BWR/3 plants.
Approx. 14 AORs.
Completion: 4Q2018
Periodic Breakaway Tests
Periodic Breakaway Tests
Periodic Breakaway Tests
Periodic Breakaway Tests
Periodic Breakaway Tests
Periodic Breakaway Tests
Periodic Breakaway Tests
NRC Review
Review Track #2 LARs.
Completed: 4Q2019
NRC Review
Review Track #3 LARs.
Completed: 4Q2020