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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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585TH MEETING

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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OPEN SESSION

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WEDNESDAY

JULY 13, 2011

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ROCKVILLE, MARYLAND

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The Advisory Committee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B3, 11545 Rockville Pike, at 8:30 a.m., Said Abdel-Khalik, Chairman, presiding.

COMMITTEE MEMBERS:

SAID ABDEL-KHALIK, Chairman

J. SAM ARMIJO, Vice Chairman

JOHN W. STETKAR, Member-at-Large

SANJOY BANERJEE, Member

DENNIS C. BLEY, Member

MARIO V. BONACA, Member

CHARLES H. BROWN, Member
MICHAEL L. CORRADINI, Member
DANA A. POWERS, Member
HAROLD B. RAY, Member
JOY REMPE, Member
MICHAEL T. RYAN, Member
WILLIAM J. SHACK, Member
JOHN D. SIEBER, Member

NRC STAFF PRESENT:

ZENA ABDULLAHI, Designated Federal Official
STEVE PHILPOTT
PETER YARSKY
MICHAEL SCOTT
TARA INVERSO
MICHELLE FLANAGAN
PAUL CLIFFORD
ANDREW CARRERA
DAVID ESH
CHRIS McKINNEY
LARRY CAMPER

ALSO PRESENT:

KEN YUEH

A G E N D A

P R O C E E D I N G S

(8:29:00 a.m.)

CHAIRMAN ABDEL-KHALIK: The meeting will now come to order. This is the first day of the 585th Meeting of the Advisory Committee on Reactor Safeguards.

During today's meeting, the Committee will consider the following. One, Safety Evaluation Report Associated with NEDC-33173, Supplement 2, "Analysis of Gamma Scan Data and Removal of Safety Limit Minimum Critical Power Ratio Margin." Two, 10 CFR 50.46(c) Emergency Core Cooling System Rulemaking. Three, Technical Basis and Rulemaking Language Associated with Low-Level Waste Disposal Site-Specific Analysis. And, four, Preparation of ACRS Reports.

This meeting is being conducted in accordance with the provisions of the Federal Advisory Committee Act. Ms. Zena Abdullahi is the Designated Federal Official for the initial portion of the meeting.

Portions of the session dealing with the Safety Evaluation Report associated with NEDC-33173 may be closed in order to protect information designated as proprietary by GEH.

We have received no written comments or

requests for time to make oral statements from members of the public regarding today's sessions.

There will be a phone bridge line. Members of the public will be listening to the discussions regarding 10 CFR 50.46(c), Emergency Core Cooling System Rulemaking.

To preclude interruption of the meeting, the phone will be placed in a listen-in mode during the presentations and Committee discussions.

A transcript of portions of the meeting is being kept, and it is requested that the speakers use one of the microphones, identify themselves, and speak with sufficient clarity and volume so that they can be readily heard.

We will now proceed to the first item on the agenda, Safety Evaluation Report Associated with NEDC-33173 Supplement 2, "Analysis of Gamma Scan Data and Removal of Safety Limit Minimum Critical Power Ratio Margin." Dr. Banerjee will lead us through that discussion.

MEMBER BANERJEE: Thank you, Mr. Chairman.

For those of you who were not here in 2007, I need to give you a little background, because otherwise this will be a little obscure as to what we are doing here.

We considered at that time --

(Off the record comments.)

MEMBER BANERJEE: But in 2007, we considered the matter of GE methods being applied to MELLA+. Don't ask me what it stands for, but I can tell you what it does.

So, when you operate a reactor from say 100 percent through its stretch of 5 percent, eventually to 120 percent, then this is called an Extended Power Uprate, and we've dealt with a lot of these.

And, of course, what happens at that point is that you're in a situation where you can control the reactor by inserting and withdrawing rods, but you lose the ability to be able to control it by controlling flow, control the reactivity. So, what MELLA+ tries to do is to take this 120 percent power and allow you to go down to flows as low as 80 percent of the rated flow at 120 power, and then between 80 percent of the rated flow and about 55 percent, or thereabouts, the power has to decrease, and that defines the top of the operating domain. I'm sure they'll show you a picture or something.

So, this expanded domain now allows you higher power to flow ratios. And this gives you, of course, more operating flexibility for the reactor, which is a good thing, but it subjects the fuel to greater demands. Let's put it this way.

So, to enable MELLA+, what GE did and others as well, was come up with fairly innovative new types of fuel designs which already had been tested and things like that. And then they also designed the detect and suppress system which -- because the system becomes more susceptible to instabilities, it tries to take care of this problem.

So, that was what it was all about. And then they applied fairly old methods which were -- I don't know if you want to say old methods, but let's say approved methods, historically approved methods, or accepted methods to these conditions of higher void fractions that you get, higher flow ratios and so on, which were somewhat outside the domain of these methods that had been originally developed.

So, we went through a whole long exercise, the Staff did, to look at the applicability of these methods, and various mods, and so on. And we came up with a letter somewhere in 2007 which we agreed with the -- concurred with the Staff who had accepted these methods with several conditions.

I don't want to make this into a long

preamble, but some of these conditions were additional uncertainties that were put on critical power issues, both the safety limit and the operating limit. Okay? And some limitations where if you have to go to a new fuel design, it had to all be looked at again, and so on. And there was a lot of other conditions and limitations put on ATWS and things like that, which I won't go into right now, which was part of our letter.

Anyway, today we are dealing with two uncertainties. One is associated with the safety limit critical power ratio under EPU conditions. Because of uncertainties in the -- let's say the predictive capability of the various methods applied, there was an additional uncertainty of .02 put on this safety limit critical power ratio under EPU conditions.

For MELLA+ conditions, which now is not just 120 percent power, if you like, originally licensed thermal power at rated flow, but goes down through lower flows, like 80 percent of the flow at 120 percent power, can do that.

Because of that, there was an uncertainty which was put on MELLA+ conditions, which is this expanded domain, which was .03. Okay? So, both those limits could be, let's say, reduced -- both those uncertainties by new data, by proving that the methods were sufficiently accurate. And that's -- those are the two issues we are specifically addressing today. Not the operating limit, CPR, not any of the other conditions. Okay?

So, with that background, we have to determine whether these uncertainties should be removed which would, of course, give some operating benefit. And we'll hear -- listen to what GE and the Staff have to say. So, I'm going to turn it over to Steve Philpott of the Staff, who will make some introductory comments. We had a Subcommittee meeting on June 7th, and this is really the full Committee.

Okay, Steven, it's all your's. From now on you run the show.

MR. PHILPOTT: Okay. Good morning. Thank you, Dr. Banerjee. And good morning to everyone. Again, my name is Steve Philpott, I'm a Project Manager in NRR, responsible for working interaction with GE-Hitachi in nuclear fuels, and managing the topical report process.

Dr. Banerjee, you've done such a good job of laying out the background, I'm not sure my introduction is going to be all that needed, but I'll step you through it just very, very briefly. And if you look on the agenda, I'll give you a very quick overview of this review. And then we'll have GE-Hitachi come up and make their presentation first, followed by the Staff presentation.

MEMBER BANERJEE: And after you speak, we'll go to closed session.

MR. PHILPOTT: Yes. Right after me, we'll go -- GE-Hitachi's presentation does involve proprietary information, so go straight to closed session.

So, I have just a few slides and, actually, kind of summarizes similar to what you said. The interim methods when we approved the topical report, I believe the SE was issued in January of 2008 for GE-Hitachi's interim methods, applying their methods to EPU and MELLA+.

We have 24 limitations and conditions in that Safety Evaluation, and GE-Hitachi has committed to provide additional data to try to address and remove some of those limitations and conditions.

Two of the limitations in that original SE are what Supplement 2 aims to address, and what Dr. Banerjee was referring to. Limitation 4 was this additional .02 to be added to the safety limit minimum critical power ratio for expanded or extended power uprate conditions. And Limitation 5 had an additional .01 added to that .02, so a total of .03 for MELLA+ conditions. And both GE-Hitachi's and the Staff's presentations will give you more details on that breakdown to further explain that.

Supplement 2 requests removal of those two limitations and conditions, does not request any other changes to the limitations and conditions in the Staff's original SE.

In the Subcommittee we went through -- kind of refresh the memory of the full roadmap. There is a roadmap to get -- to address several of these limitations and conditions and get to, I guess, an end state which we would call kind of a final methods approval where GE-Hitachi hopes to remove some of those other ones.

The emphasis here is just to emphasize again that Supplement 2 that we're addressing today only addresses those two limitations that we just told you about. And you see SE Appendix I, the approval or the Safety Evaluation, if it's issued, would become Appendix I to -- the way we're going to keep track of all these is make them appendices to the original SE, and have them all eventually in one larger document.

This Supplement was submitted in three

parts based on three different Gamma Scan campaigns which GE submitted in order to submit the additional data to try to qualify --

VICE CHAIR ARMIJO: Steve, is there any other supplement in the pipeline?

MR. PHILPOTT: There are -- right now Supplement 1, which addresses the operating limit in CPR has been submitted, and is currently being looked at and reviewed by Staff.

Supplement 4 is just about finished. That's just a limitation plan. And Supplement 3, so we're kind of going backwards in order, unfortunately, in terms of numerical order. But Supplement 3 you saw last year, which was -- extended the approval to GNF2 fuel, so that was approved.

Supplement 2 involved three cycles of Gamma Scan Data, two from Cofrentes and -- bundle Gamma Scan Data from Cofrentes, and one cycle pin-wise Gamma Scan Data from FitzPatrick.

And, again, this is -- as Dr. Banerjee mentioned, this was aimed at further qualifying the methods and addressing some of the additional uncertainties that -- the reason for these adders in the first place were some of these uncertainties. And you'll see more details in the Staff's presentation about that, as well.

And that gives you a very broad overview. I don't want to spend too much time in this introductory stuff. I'll turn it -- unless there's any other questions for me, I'll turn it over to Dr. Brian Moore from GE-Hitachi.

MEMBER BANERJEE: We should close the meeting at this point.

CHAIRMAN ABDEL-KHALIK: Is there anybody on the phone? We need to make sure that the phone line is closed.

MR. PHILPOTT: I don't believe so.

MEMBER BANERJEE: So, we go into closed transcripts.

MR. PHILPOTT: Okay.

(Whereupon, the proceedings went off the record at 8:43:17 a.m., to begin Closed Session, and went back on the record at 10:22:25 a.m.)

MEMBER BANERJEE: All right. Go ahead, Peter.

MR. YARSKY: All right. I hope to go through this material relatively quickly.

The IMLTR Supplement 2 sought to remove two penalties applied to the SLMCPR, one for EPU operation and one for MELLA+ operation, and sought no other changes to the conditions and limitations in the Staff's SE.

As we talked about, the Staff review considered the Gamma Scan results, the TIP data, comparison with key operating parameters, LPRM calibration, and the applicability of MELLA+ operation.

In conclusion, Limitations 4 and 5 of the Staff's SE for the IMLTR impose adders. GEH requested the NRC review and approve Supplement 2 to remove these limitations. Based on the Staff review, the Staff concurs with GEH with one exception, and that is the Limitation 5 which imposes a 0.03 adder to the cycle-specific SLMCPR, while it is revised is only reduced to 0.01, as opposed to being fully removed. And Limitation 5 will now stipulate an adder of 0.01 for MELLA+ operation. That's all I have for concluding remarks.

MEMBER BANERJEE: Thank you very much. GE, are there any remarks you want to make?

MR. MOORE: This is Brian Moore. GE prepared the Supplement to demonstrate the resiliency of our methodology; hopefully, answering many questions that were raised in 2007. A great deal of effort was made by both GEH, and also our customers, to obtain this data set presented to the Staff. Thank you for the questions both from the Staff and from the ACRS panels. We believe that it has helped clarify the record. Thank you.

CHAIRMAN ABDEL-KHALIK: None of the data that was presented today covered conditions that would be considered MELLA+. So, why are we just looking at the differential adder, the .01, rather than the .03 for MELLA+?

MR. YARSKY: What I covered in the closed session was the nature of what comprises that 0.03.

CHAIRMAN ABDEL-KHALIK: But, nevertheless, I fully understand that, but that didn't cover conditions pertaining to MELLA+.

MEMBER BANERJEE: We are in open session.

CHAIRMAN ABDEL-KHALIK: I understand.

MEMBER BANERJEE: Right.

MR. YARSKY: I am trying to formulate an answer that would be appropriate in open session.

MEMBER BANERJEE: If you wish, we can go back to closed session.

VICE CHAIR ARMIJO: We can close it again.

MEMBER BANERJEE: We can close the meeting, if you'd prefer.

CHAIRMAN ABDEL-KHALIK: Yes, if you'd

like, because this is a central issue in my mind.

MEMBER BANERJEE: Perhaps, why don't we close the meeting for five minutes.

CHAIRMAN ABDEL-KHALIK: Right. That's fine.

MEMBER BANERJEE: Okay?

CHAIRMAN ABDEL-KHALIK: Okay.

MEMBER BANERJEE: Can we do that, go into closed session. Zena, please insure that we are --

CHAIRMAN ABDEL-KHALIK: Please.

MEMBER BANERJEE: -- in closed session. Thank you.

(Whereupon, the proceedings went off the record at 10:25:47 a.m., and went back on the record at 10:28:46 a.m.)

MEMBER BANERJEE: Okay. So, Mr. Chairman, we are done, and I'd like to thank both GE and the Staff for a very complex matter well explained.

CHAIRMAN ABDEL-KHALIK: Thank you.

MEMBER BANERJEE: Thank you.

CHAIRMAN ABDEL-KHALIK: Thank you very much.

At this time, we are scheduled for a 15-minute break, so we will reconvene at 10:45.

(Whereupon, the proceedings went off the record at 10:29:08 a.m., and went back on the record at 10:44:45 a.m.)

CHAIRMAN ABDEL-KHALIK: We are back in session. At this time, we'll move to Item 3 on the agenda, 10 CFR 50.46(c), Emergency Core Cooling System Rulemaking. And Dr. Armijo will lead us through that discussion.

VICE CHAIR ARMIJO: Okay. Mr. Chairman and members, as you recall a few weeks ago we reviewed a number of regulatory guides related to cladding embrittlement. The objective there is to assure that we have coolable geometry in the core in the event of a loss of coolant accident. The issues there address the potential fracture of undeformed fuel rods resulting from embrittlement due to oxidation and hydrogen.

Today we're going to talk about a part of the fuel rod that is already fractured. In fact, it has ballooned and burst, and that is also in the core and has to be addressed as part of the ECCS Rulemaking. So, this is strictly a briefing. The Staff has not requested a letter on the matter. But, of course, it's up to the Committee to determine what we will do.

So, I would like to turn it over to the

Staff, and I believe that's going to start off with -- where is Ms. Gibson? Oh, please go ahead.

MR. SCOTT: Thank you. Good morning. Contrary to the agenda, I'm not Kathy Gibson. Unfortunately, Kathy couldn't be here today. I'm Mike Scott. I'm the Deputy Director in the Division of Systems Analysis in the Office of Nuclear Regulatory Research.

As Dr. Armijo discussed, this is the latest in a series of interactions regarding the 10 CFR 50.46 rulemaking effort. We briefed the Subcommittee on this subject on June 23rd.

By way of background, in May 2008 we issued a Research Information Letter entitled, "Technical Basis for Revision of Embrittlement Criteria in 10 CFR 50.46." It recommended that the experimental results from our LOCA research program be used as the basis for rulemaking to revise the cladding embrittlement criteria in 10 CFR 50.46. Then, in December of that year, we briefed you on the LOCA research program findings and the rulemaking strategy for the ECCS requirements.

Since then, as you know, we have been working on the rulemaking revisions. At the same time we were completing an ongoing research program at

Argonne and Studsvik specifically designed to investigate the mechanical behavior of the ballooned and rupture region. Today's briefing is on the results and conclusions of this research program.

As we will discuss today, the results indicate that the planned additional measures are appropriate to address cladding behavior at high burnup. The report documenting these results and conclusions, along with the necessary updates to the RIL will be provided as enclosures to the proposed rule package that we're scheduled to brief you on in February of 2012. So, the briefing today is intended to familiarize you with this material in anticipation of the future briefings.

A formal review of the information presented today will be part of the proposed rule package, so we are not requesting a letter on this subject at this time. However, as always, the Committee's feedback is welcome.

So, let me introduce the Staff who are here today to brief you, most of whom I'm sure you already know; Tara Inverso of the Office of Nuclear Reactor Regulation, Division of Policy and Rulemaking will begin today's briefing with the status of the rulemaking project. Following Tara, Michelle Flanagan of the Research Staff will present a briefing on the results and conclusions of the research program, and will discuss how these results and conclusions are being used to support the treatment of the ballooned and ruptured regions in the proposed rule. John Voglewede, our Senior Level Advisor for Fuels in the back, and Paul Clifford from NRR next to me are also here to answer questions, as needed.

So, with that, I'll turn the floor over to Tara.

MS. INVERSO: Thank you. As Mike mentioned, my name is Tara Inverso, and I'm the Project Manager for the 50.46(c) rulemaking. And as he also mentioned, we're here today to present the regulatory basis which informs regulatory treatment of ballooned and ruptured regions of the fuel rod within the proposed 50.46(c) rulemaking. And as Mike also mentioned, this is for familiarity in preparation for the briefings on the complete proposed rulemaking package later on this calendar year.

Today's meeting will begin with this presentation, which is an overview of the rulemaking activities, and will go directly into Michelle's technical presentation. The industry will then remark on the technical document that was made publicly available prior to the Subcommittee meeting. And it will conclude with a discussion led by the ACRS members.

This rulemaking has four main purposes. The first is to incorporate findings of the fuel cladding research program, and that research program focused on high exposure of fuel cladding under accident conditions, and identified previously unknown embrittlement mechanisms, and also expanded NRC's knowledge of previously identified mechanisms.

The Commission has also provided direction on this rulemaking through an SRM, SECY-02-0057. They directed the Staff to replace the prescriptive analytical requirements within 10 CFR 50.46 with performance-based requirements. And in developing the performance-based requirements, they directed the Staff to expand the applicability of the rule to all cladding materials. Right now, the current rule limits the cladding materials to zircaloy and ZIRLO. And the Staff is also expanding applicability to all fuel designs.

That last objective was also requested through a Petition for Rulemaking which was admitted in March of 2000 by the Nuclear Energy Institute, and docketed as PRM-50-71.

And lastly, there's another Petition for Rulemaking that this proposed rulemaking will address. That's PRM-50-84, which was submitted by Mr. Mark Leyse in March of 2007. And he requested that the NRC require licensees to consider the effects of crud on the fuel cladding.

Recent developments, the Office of Nuclear Regulatory Research has drafted three draft reg guides. We presented those to the ACRS Subcommittee on May 10th, 2011, and the full Committee on June 8th, 2011. Those three, the first one establishes a test procedure for measuring breakaway oxidation. The next one establishing a test procedure for closed quench ductility, and the last one establishes analytical limits for zirconium-based alloys.

The Staff is continuing to evaluate the results of fuel fragmentation and dispersion research. We talked to the full Committee about that on June 8th briefly, and again to the Subcommittee on June 23rd. We have no updates at this point on that phenomenon.

The purpose of today's briefing is to discuss the mechanical behavior of ballooned and ruptured cladding technical document.

As mentioned, we plan to brief the ACRS Subcommittee on the full proposed rule package on

December 15th, 2011, and then return to the ACRS full Committee on February 9th, 2012. And we will deliver the proposed rule to the EDO on February 29th, 2012.

And that concludes the presentation. If there are any questions?

CHAIRMAN ABDEL-KHALIK: Keep going.

MS. INVERSO: Okay. With that, I will turn the presentation over to Michelle Flanagan.

MS. FLANAGAN: Okay. My name is Michelle Flanagan, and I work in the Office of Research in the Fuel and Source Term Team. And my presentation today will cover the contents of a technical report titled, "The Mechanical Behavior of Ballooned and Ruptured Cladding." And the purpose of this document is to serve as the technical basis for the treatment of ballooned and ruptured cladding in the new rulemaking for ECCS requirements.

And the presentation today will, for the most part, follow the contents of the report. So, we'll begin with a review of the regulatory history of the balloon, and then we'll present the results of NRC's integral LOCA Research Program, and then explain how these results are being used to support the treatment of the ballooned region within the rulemaking to revise 50.46(b).

So, if we look through the overarching requirements of ECCS systems, we see the General Design Criteria in 50.46 require an emergency core cooling system is available to insure that if a loss of coolant accident took place, the core could be -- remain in a geometry that's amendable to cooling, and that decay heat is removed to insure long-term cooling.

And in Commission hearings in the 1970s, the coolable geometry was established as something that could be maintained if the fuel cladding remained ductile. And this position mostly fell out of the belief that specific predictions and quantifications of local loads wasn't possible, and that maintaining cladding ductility was the best approach to preserving coolable geometry.

At that time, ring-compression data among other experimental observations was used to establish a ductility threshold, and that criteria that were established were directly cited in the rule. And that's where we have 17 percent, came out of that testing program.

And over 10 years ago, the question was first posed, are these criteria that are in 50.46(b) currently, are they appropriate for high-burnup cladding? And like the program that defined LOCA acceptance criteria in 1973, the test program that we embarked on to investigate high-burnup cladding also used ring-compression tests, and largely followed the same technical basis that had been established with the original criteria.

And the conclusion of that test program was that the oxidation criteria were not sufficient for high-burnup cladding. And, particularly, what was found was that hydrogen has a significant impact on the cladding embrittlement. The greater the hydrogen content, the less oxidation is required to embrittle the cladding material.

And then out of these findings, the Office of Research issued RIL-0801, which cited a trend of embrittlement oxidation as a function of pre-transient hydrogen, and established a decreasing threshold as a function of hydrogen.

MEMBER POWERS: When you add hydrogen into zirconium, are you injecting or extracting electrons out of the Fermi band?

MS. FLANAGAN: Am I injecting or --

MEMBER POWERS: Extracting electrons out of the Fermi band?

MS. FLANAGAN: I don't know that. But is

that -- is it a question of what leads to the oxidation and the --

MEMBER POWERS: Well, the contention is that hydrogen operates synergistically with oxygen to enhance embrittlement. And when we think about alloying of oxygen, we know that the FERMI band is very sensitive in that alloy. And, in fact, most alloying with zirconium we can explain what goes on in the FERMI band. And one would think that oxygen and hydrogen would act in opposite directions on the electron concentration in the FERMI band. So, trying to understand how it operates synergistically is interesting.

MS. FLANAGAN: Yes. We didn't go into that level of detail with what is going on at that level. What I do know is that trends -- the larger the hydrogen content, the greater the solubility for oxygen, and the greater the diffusion -- or the faster the diffusion of oxygen into the base metal is. So, whichever way the FERMI bands would be for those types of observations might be a conclusion that's available. But those are the trends that we observed, not in this research, but prior to this, and what we know about the content of hydrogen and how it impacts oxygen.

Does that answer your question?

MEMBER POWERS: No.

(Laughter and simultaneous speech.)

MS. FLANAGAN: Right, but that's what we know about hydrogen and oxygen, and how they're related, and what kind of trends we see. And that's why when we see increasing hydrogen content, what we're really seeing is that oxygen is absorbed faster into the base metal, and at more significant amounts. And that's what leads to the embrittlement that we observe, and that's why we see a decrease in the amount of oxidation that it really takes to develop brittle material.

MEMBER POWERS: Well, you know that when the hydrogen goes into the alloy, you expand the stability range to the beta region. Right?

MS. FLANAGAN: Yes.

MEMBER POWERS: And narrow the expanse at the alpha region. Oxygen does exactly the opposite, so I guess what you're saying is that oxygen is very soluble in the body-centered cubic.

MS. FLANAGAN: I may be saying that. I mean, basically, we're not observing the trends at that level. We're looking for the material behavior at a macroscopic level, what is the ductility? How brittle is the material? So, of course, all of that is operating and it's at a level of understanding that is underneath our observations.

So, this is the trend that we observed. As I said, with increasing hydrogen we see that it takes less oxidation to develop brittle behavior. And with these results and RIL-0801 being issued an interoffice working group was formed in order to revise the regulations in 50.46.

And in developing that rule language, one of the questions that the Staff focused on was how to treat the portion of the fuel rod predicted to balloon and rupture during a LOCA. And, in particular, the Staff questioned whether the criteria that had been observed in ring-compression tests was appropriate to apply in the balloon region. And if we look at the way that the balloon is treated in the current regulations, it's articulated directly in the rule language. And it says to take the oxidation limit and apply it in the balloon where you're taking the thin wall region, taking the average wall thickness and using that as your denominator in your percentage of cladding reacted. And then you're taking double-sided oxidation. So, all that is specified in the rule. It's how we say currently to apply the oxidation criteria in the balloon region, and so the Staff's question was whether that was -- continued to be appropriate with the new observations of the impact of hydrogen.

So, there's a couple of unique features of the balloon region which are really behind the question that the Staff was asking. There is -- as I mentioned before, there is a variation in the wall thickness, so the rule language today says to take the average of the wall thickness. And we can see that with this large variability, you'll have some regions which are thicker than the average and thinner than the average, and you can imagine that the thinner than average regions may be brittle.

In addition, we have seen large uptake of hydrogen above and below the rupture opening, and these regions are also observed to be brittle. So, in the balloon region we have localized regions which are known to be brittle. So, the question is whether our oxidation criteria applied in the balloon region preserves the necessary properties during a loss of coolant accident.

I should mention that both of these phenomenon were understood. The first to the left was understood at the time that the original rule was written. It was clear that there was going to be non-uniformity. And the second observation of high hydrogen regions was observed in the `80s in programs in the United States and Japan. And at the time that the research results were evaluated, it was determined that there was sufficient conservatism in the rule that this -- the presence of these brittle regions was acceptable, and no changes to the rule structure were made at the time that these results were found.

MEMBER POWERS: I'm struggling to understand the plot.

MS. FLANAGAN: Yes.

MEMBER POWERS: What is red, and what is blue?

MS. FLANAGAN: Oh, yes. Blue is the hydrogen, and here we have tracked the -- each of these measurements were made and tracked the hydrogen content of the material. And it's a weight percentage. The oxidation -- the oxygen is the ECR value, or no. Here it's weight percent. The one thing to note is that thinned walled regions the presence of oxygen is going to be -- it's not -- it's magnified I guess is the word, because of the thinned wall. So, some of the increase in the center region is due to the wall thinning.

VICE CHAIR ARMIJO: But you don't have a lot of hydrogen there.

MS. FLANAGAN: Correct.

VICE CHAIR ARMIJO: You make the point, the hydrogen is all at the ends of the balloon region.

MS. FLANAGAN: Right.

MEMBER POWERS: As far as I can tell, at zero there's no metal there either. That's what I don't understand, is your picture has a gap, your graph says there's no hydrogen there, which I can believe, but there's a whole lot oxygen there.

MS. FLANAGAN: Yes.

MEMBER POWERS: But there's no metal -- I mean, there's no material there.

VICE CHAIR ARMIJO: I don't think those were the same samples.

MS. FLANAGAN: The value is an average for a ring section, so it's --

MEMBER POWERS: If you look at the ring, there's a gap.

MS. FLANAGAN: Okay. This is axial distance, and then that's the circumference. So, I don't mean to imply that these two figures are -- this isn't measurements of this ring. This is just to illustrate the rupture circumference. These are measurements that are made along the axial length, so here is the burst center. And it would be the elevation that this ring was taken. And then these measurements are above and below. But this value is taken of a whole entire ring.

MEMBER POWERS: Oh, it's all of that ring at that level.

MS. FLANAGAN: Right. So, this would be -- if I melted this down and I made a measurement of the hydrogen and oxygen, that's where these two --

MEMBER POWERS: Now I understand.

MS. FLANAGAN: Okay. Sorry about that. That may have been confusing.

Okay. So, looking at the historical treatment that the balloon region had, RIL-0801 commented that no criteria has been found that would insure ductility in the cladding balloon. And further stated that loss of ductility in the short portion of the fuel region shouldn't lead to an uncoolable geometry, as long as the amount of oxidation in the balloon region remains limited in the current manner.

And when I say "in the current manner," I'm referring to the accommodations that are outlined in the current 50.46 rule, where you're taking the average wall thickness and you're doing double-sided oxidation.

So, the Staff and the Working Group focused on how to document and support this conclusion in the Statements of Consideration for the rule.

VICE CHAIR ARMIJO: Now, back up, Michelle. We're uncoolable geometry, and we have -- has the Staff put to bed the issue of the ballooning causing loss of coolable geometry?

MS. FLANAGAN: As far as flow blockage?

VICE CHAIR ARMIJO: Yes.

MS. FLANAGAN: Yes, that's not handled with this research. This research assumes a certain balloon, and then looks at the mechanical --

MEMBER POWERS: I thought Rittenhouse had done that back in the `60s or something like that.

MS. FLANAGAN: Yes. I'm not too familiar with that, but it's done separately as a part of LOCA analyses.

VICE CHAIR ARMIJO: Okay. So, as far as this rulemaking that's not an issue, or is it?

MS. FLANAGAN: I think I'll turn that over to Paul just to be clear, but -- I mean it's not in the --

(Simultaneous speech.)

VICE CHAIR ARMIJO: -- coolable geometry

has all got to come together in one spot.

MR. CLIFFORD: Right. Yes, the purpose of this research was really to look at the material strength, material ductility of high-burnup cladding. There was no integral LOCA tests done to further evaluate or inform the treatment of the balloon region with respect to the geometry of the balloon. We still rely upon existing reg guides --

MEMBER POWERS: Any changes in the ballooning for high-burnup from in the geometry of the balloon are actually in the direction of greater flow, aren't they as you go to higher burnup?

MR. CLIFFORD: Yes. I would imagine that changes in hydrogen content in burnup irradiation hardening would affect the size and shape of the balloon. That's true.

MEMBER POWERS: The biggest balloons you're going to get is on pristine clad, I would think.

MR. CLIFFORD: Correct. And right now, when they qualify a new cladding alloy they would do separate effects testing where they would do balloon testing to insure that their LOCA models were conservatively treating the size and shape of the balloon.

MS. FLANAGAN: Okay. So, in an effort to support the Staff discussion about the treatment of the balloon region, the Working Group staff referred to the results that were coming out of NRC's integral LOCA research program. And in this program, tests were conducted at Argonne National Lab, and Studsvik Laboratory in Sweden. And in these tests single rods were brought through a simulated LOCA transient through heat up, oxidation at high temperatures, cooled down to 800 degrees C, and then a quench simulation.

And in these tests, particularly the tests at Argonne where we used as-fabricated cladding, there was a large range of balloon strains that were investigated. And then -- and here's an image of the test train that was at Studsvik to give a sense of what it looked like experimentally.

After the tests, the segments that were ballooned, and burst, and quenched were taken through mechanical tests, which a four-point bend test which subjected the entire span of the balloon length to a uniform bending moment. And as I pointed out before, we know that there are regions of high hydrogen content, as well as the extremely thin region in the center of the balloon, so having the uniform bending moment really allowed us to investigate where the weakest location was, and investigate the competition between the thinnest region, which has the highest ECR, and the regions with high hydrogen content.

And from the load-displacement curves of the four-point bend tests we were able to analyze a couple of parameters. One was to look at the maximum plastic displacement as a measure of ductility. Another was to examine the maximum applied energy as a measurement of toughness. Another was to analyze the maximum bending moment as a measure of strength. And then, finally, in the tests we observed the failure location. And I'll say a little bit more about that next.

In comparing the load-displacement curves and the parameters that we extracted from the load-displacement curves between different tests, we were able to investigate the influence of oxidation, irradiation, balloon size, bend test temperature, and hydrogen content.

So, I'm going to start with presenting results that were conducted at Argonne National Lab, and all of these tests were on as-fabricated cladding. I don't intend to go through this table. I'll show more usefully, or in a clearer way the results on a plot in which you'll be able to see some of the trends.

Two things I want to point out while I'm on this slide, though, is that the rupture strains in these tests varied from 21 percent all the way to 70 percent. So, we had a large range of ballooning strains.

Another thing I want to point out is that all of these samples survived quench, so they survived the quench process which produces its own significant loads in both the hoop and axial directions. So, we really want to point out that all of the samples had some mechanical properties that were measured in our test.

VICE CHAIR ARMIJO: Were they pre-hydrided, Michelle?

MS. FLANAGAN: None of the samples on this graph were pre-hydrided. We do have --

MEMBER CORRADINI: But there was another group that you showed us that was, right?

MS. FLANAGAN: I have some plotted on the graph.

MEMBER CORRADINI: Oh, that's what I thought. Okay.

VICE CHAIR ARMIJO: Okay.

MS. FLANAGAN: Yes.

VICE CHAIR ARMIJO: And this was all one material, zircaloy?

MS. FLANAGAN: Yes, Zircaloy-4.

VICE CHAIR ARMIJO: Okay.

MS. FLANAGAN: No, sorry, it was ZIRLO. Sorry.

VICE CHAIR ARMIJO: ZIRLO? That's what I thought.

MS. FLANAGAN: Yes, it was ZIRLO, and it was designed to be comparable directly to the material at Studsvik, which was ZIRLO. That's what we had available to test for irradiated material.

So, as I said, there's an easier way to show these results, and one of them is to look at the bending moment as a function of the CP-ECR. So, here we have all of the results plotted as a function of oxidation level. And we notice that the general trend is that with increasing oxidation we have a reduction in the maximum bending moment.

I want to point out that on this slide we have two sort of sets of data. We have the data distinguished into two categories, and it's as a function of large balloons and small balloons. So, we have circles indicating very small balloons, or less than 40 percent, and greater than 40 percent, and then squares indicating small balloons at less than 33 percent.

In addition, we have one data point that was measured at room temperature, the bending test was conducted at room temperature, while the other ones were conducted at elevated temperatures consistent with the ring-compression test data.

And I'll point this out on the next slide, but we have two different failure locations. And in this plot, some of the points failed at the center of the rupture opening, and some of them failed at the location of maximum hydrogen content. And yet, we have a general trend of as the oxidation increases the bending moment decreases. So, we don't see a large distinction between results that failed during -- at the center of the burst opening, or at the region of high hydrogen content.

So, as I said, we observed two types of failure. On the left, we have samples which failed at the high hydrogen regions. And, generally, these were observed in rods that had very small balloon sizes.

VICE CHAIR ARMIJO: Very what? I didn't hear you.

MS. FLANAGAN: Very small balloon sizes.

VICE CHAIR ARMIJO: Okay.

MS. FLANAGAN: And, alternatively, we had failure that occurred right in the center of the rupture opening. And this was always the case for large balloons, and then some of the small balloons also had this failure location.

The values of failure energy were also shown to decrease with increasing oxidation. And, again, even through a wide range of values for ballooning strain.

So, following the as-fabricated cladding testing program at Argonne, four irradiated rods were tested at Studsvik in NRC's integral LOCAL research program. And I should say that prior to testing at Studsvik, we did a lot of work between Argonne and Studsvik to compare their apparatus, to compare the results that they were getting, and we used as-fabricated cladding in both cases to benchmark the equipment to insure that we when were done we could really put all of these points on the same plot.

The sample material that we had available at Studsvik was around 70 gigawatt-days per ton burnup, and the hydrogen content was around 200 weight ppm. So, given that the weight -- the hydrogen content was 200, we targeted our testing at Studsvik to be just above and just below the values at which we expect embrittlement based on our ring-compression test results. And then we also conducted a test at 17 percent oxidation, and zero percent. So, basically, it was ramp to rupture and then the test was terminated.

I want to say that the ECR value is a calculated value, so in all of the results that I've presented previously, and all of the ones that I'll present following this, the value of ECR is calculated based on the current construction in the rule. So, the wall thickness is the thinned wall thickness. And it's considering double-sided oxidation.

So, as I said, we conducted four tests at Studsvik, and there's a table here which presents some basic features of each test. And I'll go right into comparing the results of these tests with the ones from Argonne.

So, on this figure we have the values of the Studsvik bend tests, and a couple of recent pre-hydrided tests plotted with the values for as-fabricated cladding that I presented earlier.

VICE CHAIR ARMIJO: Michelle, could you just back up a little bit to that picture where the balloon region --

MS. FLANAGAN: Yes.

VICE CHAIR ARMIJO: Now, in the bend tests did all of these fail in the balloon region?

MS. FLANAGAN: Yes. In the Studsvik tests they all failed in the center of the rupture opening.

VICE CHAIR ARMIJO: Okay. But not during the quench.

MS. FLANAGAN: Correct, there was no -- they were in tact following quench.

So, again, with the Studsvik results and the pre-hydrided results we continue to see that the increasing oxidation leads to a decrease in bending moment demonstrating that limiting oxidation in the balloon region is appropriate. The balloon region should have an oxidation limit applied.

The values of bending moment for irradiated fuel were shown to be reduced relative to the as-fabricated values. And recent re-hydrided data show that the bending moment of pre-hydrided material also is reduced from that of as-fabricated cladding for the same oxidation level.

And then what we found was that applying the proposed hydrogen-dependent oxidation limit in the balloon preserves favorable mechanical properties. And to say that, I'll point out that this material that was tested at Studsvik under the new criteria would be subjected to an oxidation limit of 12 percent. Given that it had 200 weight ppm, it would be limited in oxidation to 12 percent, which is a value around -- in between these points, which would preserve a bending moment around between 8 and 9 newton-meters. And we see that for 17 percent as-fabricated cladding we have less than that. So, in other words, we're saying that the irradiated materials preserved properties are greater than that of the as-fabricated cladding at 17 percent. And we saw the same general trends when we examined failure energy.

So, there is a couple of research program conclusions that I want to make, or reiterate. All of our samples survived quench with some margin of mechanical properties. The values of bending moment and failure energy were shown to decrease with increasing oxidation even through a wide range of ballooning strains. Even though very high values of hydrogen content were observed within the balloon region, no matter where the failure was observed the residual bending moment remained a function of oxidation.

Also, the value of bending moment and failure energy reveal a hydrogen effect on the mechanical behavior in the balloon region that should be accounted for. And when the new proposed hydrogen-based criteria is applied in the balloon region, the mechanical properties in this region are maintained to at least that of fresh cladding.

So, I want to address these research program conclusions within a regulatory context in three aspects. First, in the Staff's position for the current rule, or for the revision of the rule, these research results have been used to support using a time and temperature limit based on ring-compression test data to limit oxidation in the entire region -- entire fuel rod, including the balloon region with the provisions outlined in the current regulations, which use the average wall thickness and double-sided oxidation.

And then going forward in the future, the research conclusions didn't reveal any reason that materials that may be developed in the future that may have better embrittlement properties, that those shouldn't also apply in the balloon region.

So, we anticipate that in the future ring-compression test program and the regulatory guides that were developed can be used to characterize new cladding alloys, and current alloys at lower oxidation temperatures. And that the results from those can also be applied in the balloon region, so there wouldn't be a need to go through a four-point bend test program, or an integral LOCA program. There was nothing in our research results that suggested that that would be necessary.

VICE CHAIR ARMIJO: Provided that the ring-compression test on the unballooned materials hydrided, or pre-hydrided were adequate, the results which demonstrate ductility.

MS. FLANAGAN: Correct.

VICE CHAIR ARMIJO: I got you.

MS. FLANAGAN: Yes. Well, we're suggesting that if the ring-compression tests show improved behavior that can be assumed for the balloon region, as well.

And the last sort of regulatory consideration for our research program results is to comment on alternative performance metrics for the ballooned and ruptured region of the fuel rod. So, there have been longstanding discussions of alternative metrics for fuel rod performance under LOCA conditions within the international community. And our position now is that these approaches really rely on detailed knowledge of LOCA loads and complex experimental and modeling research programs. And the state-of-the-art today doesn't support a regulatory position based on those proposals in the near-term. So, at this point pursuing more complex performance metrics for the ballooned and ruptured region isn't recommended.

So, I started earlier in this presentation with a quote from RIL-0801. So, given that we've learned a little bit more, and we have some results for the ballooned region, it's appropriate to revisit the conclusions of RIL-0801 and update them to the extent that we can. So, the language and the wording may not be specific, but what I really want to say with this slide is that we intend to revisit RIL-0801 and integrate the conclusions of our current program so that that document reflects our current approach to the rulemaking. And that will be something that you'll see in a final form when the rule package is complete. But it will be something along the lines of reiterating a conclusion from this Technical Report, very simply saying that this is our position on the balloon.

So, the conclusions of my presentation today are that an integral LOCA research program has generated new data and understanding of mechanical behavior of ballooned and ruptured fuel rods. These results indicate that limiting oxidation in the balloon region continues to be appropriate. The results also indicate that applying hydrogen-based embrittlement limit in the balloon preserves mechanical behavior to that of as-fabricated rods at 17 percent.

A Technical Basis Document has been written to supplement the treatment of the balloon within the proposed rulemaking, and updates to RIL-0801 have been proposed which incorporate the findings of the recent research. And that is my last slide.

VICE CHAIR ARMIJO: Okay. I've got a couple of questions, then I'll -- I'm a little confused in that the balloon region appears to be the most fragile part of the fuel rod. And, yet, when you do these experiments on unirradiated and irradiated cladding that region does not fracture during the quench. So, why wouldn't it be reasonable to conclude that the nonballooned region which can have the same amount of hydrogen would be -- should be of concern? Why shouldn't all the focus be on the ballooned region since that's the most fragile part of the fuel rod?

And I think there have been other experiments where people have again demonstrated that the balloon region does not fracture during these quenches, so that's something to think about. I've been thinking about it since our last Subcommittee meeting. I just haven't got a good answer, except that a lot of -- we know a lot more about the metallurgy of the cladding, and we've concentrated a lot on the undeformed materials in a variety of ways trying to demonstrate ductility by the ring-compression test. But then when you have the highly deformed already ruptured balloon region that you accept on the basis of strength, not necessarily ductility, and my question is if the balloon region is okay and measured on the basis of some sort of a strength or energy-absorption criterion why do we worry about the undeformed region? That's where I'm at, so I'll just let it sit for a while, because I don't have an answer yet, but you may want to comment.

MS. FLANAGAN: Well, we got into this a little bit at the Subcommittee. Effectively, there are many LOCA analyses that are limited by the balloon region, so there are many times in which you're right that that location limits the operation and what's possible in ECCS performance.

VICE CHAIR ARMIJO: But if we have a LOCA event where you'd get no ballooning, then I would argue that yes, now you've got to look at the --

MS. FLANAGAN: Right. And that's the thing, is that in cases where you're not experiencing ballooning and rupture, it's appropriate to apply an oxidation criteria. We know and have seen that the higher the oxidation is, you can get into unacceptable consequences, so there should be some oxidation limit that applies.

VICE CHAIR ARMIJO: That would be pretty low temperature if -- to avoid ballooning, you have to stay below what, your 800, something like that, Centigrade?

MS. FLANAGAN: Yes, ballooning and rupture happens at a very low temperature.

VICE CHAIR ARMIJO: So --

MS. FLANAGAN: Well, it depends on the pressure -- the differential pressures. It depends on the LOCA scenario that you're dealing with.

VICE CHAIR ARMIJO: Okay.

MS. FLANAGAN: Yes, around there.

VICE CHAIR ARMIJO: All right. Well, I've got to keep thinking about it. Any other --

MEMBER SHACK: Well, I thought one of the things that we discussed at the meeting was that wasn't always true that the balloon region was the limiting region, because you've got cooling. You could actually get less oxidation there. And, in fact, the critical region could be somewhere else, so it really -- it was very analysis-dependent. And you couldn't come to the sort of what would seem like the intuitive conclusion that the balloon region really is the --

VICE CHAIR ARMIJO: The most damaged.

MEMBER SHACK: The most damaged.

VICE CHAIR ARMIJO: Appears to be the most damaged, and the question is, is that generally true or not?

MEMBER SHACK: That didn't seem -- yes, that was the -- I thought the conclusion we came to at the Subcommittee, at least the input from the people who did the LOCA analyses said that that wasn't always the case.

MEMBER CORRADINI: It wasn't universally true. That's what I remember was said.

MEMBER POWERS: Let me understand one item. You made the point several times in the presentation that all your samples survived the quench, but that quench was a simulation of the quench for ECCS operation, or just a simple --

MS. FLANAGAN: Not really.

MEMBER POWERS: -- cool down?

MS. FLANAGAN: In these tests there was no constraint on the cladding. It was able to freely expand. So, during the quench process you're going to induce thermal expansion which would apply additional loading.

I pointed out that all the samples survived quench because there's something reassuring about that. There's something that is satisfying with the fact that we opened up the test train and it wasn't shattered. There are significant loads in quench, but they were not all simulated in these single rod tests. So, that's where the mechanical testing comes in.

MEMBER POWERS: Were any of them --

MS. FLANAGAN: What is left over after the quench? How much margin to failure do we have? So, that's what the mechanical test prior to quench is really examining.

VICE CHAIR ARMIJO: But there's the Japanese testing where they do apply a load during the quench.

MS. FLANAGAN: Right.

VICE CHAIR ARMIJO: And they find similar-

MEMBER SHACK: But I think Dr. Powers was sort of wondering whether the quench itself was, in fact, conservative or unconservative compared to what you would expect to find in an actual event. How did you do the quench in the test?

MS. FLANAGAN: Temperature-wise, it was the same temperature scenario that was established as a conservative bounding, a large break LOCA scenario that had been used for the Argonne tests. So, we could talk about whether it's -- the temperature scenario is conservative, but the fact that it doesn't include constraint would then --

MEMBER POWERS: Because I don't understand how the temperature profile would, in fact -- I don't know what conservative means exactly here. Maybe you can explain that. But it seems to me that I'm injecting an ECCS system into it that I go through a temperature scenario at least locally that would be challenging to reproduce in any way in a furnace.

MS. FLANAGAN: The temperature scenario would be difficult to -- the local temperature scenario would be difficult to simulate? I don't know. I mean, it's the same waterfront that's creeping off the surface of the cladding, so it is heated by external lamps. But the actual measurement of the temperature --

MEMBER POWERS: The only way you -- in a furnace test you can make a step change in the heat flux, but in a quench flux you have a step change in both heat flux and temperature. Those two are very different circumstances.

MS. FLANAGAN: Yes, I guess I can't answer your question other than to say that the thermocouple measured a transient and that was what it was calibrated to. And the heating is going to just do whatever it takes, apply whatever power is necessary to maintain that control thermocouple. So, you're right in that sense it might be -- I don't know, my instinct still says that if the actual front is creeping up the cladding that that local temperature gradient and that difference between just above and just below would still be quite representative.

MEMBER CORRADINI: All right. I guess, I think all he's asking -- maybe I'm misinterpreting Dana's point, but I think he's asking what's the structural boundary -- what's the -- how are you holding in that boundary condition and how are you cooling in that boundary condition, and how close is it to what you expect?

MEMBER POWERS: I mean, those are legitimate questions, but what I know is that when you subject any material to a step change in heat flux you get a different response than you get when you do both a step change in heat flux and a step change in temperature. The latter is nearly always much more damaging for material.

MEMBER CORRADINI: But they're getting both in the simulated case.

MEMBER POWERS: No, here they only get a step change in heat flux.

MEMBER CORRADINI: Well, no --

VICE CHAIR ARMIJO: Michelle, how did you do the quench --

(Simultaneous speech.)

MEMBER CORRADINI: -- wouldn't progress up the rod.

VICE CHAIR ARMIJO: In these experiments, how did you actually do the quench? Was it with --

MEMBER CORRADINI: And the heat flux does play --

MS. FLANAGAN: No, it was with water. Water came in. It was preheated water, so it came in as steam initially.

VICE CHAIR ARMIJO: Okay.

MS. FLANAGAN: And then -- yes, a reflood tank was initiated, so there was a waterfront. I can show you that illustration.

MEMBER CORRADINI: Well, I guess I misunderstood Dana's point then, because they get a quench front, and the quench front, assuming they get the right quench front rate, you're going to get this enormous change in temperature along the rod.

MS. FLANAGAN: I should say that also the power to the furnace was turned off at the second that the quench was initiated, so whatever heat is there is from the rods inertial heat.

MEMBER CORRADINI: It's stored energy.

MS. FLANAGAN: Right. So, this -- at this time here, this isn't very illustrative, but this is the quench front reaching the top of the furnace.

VICE CHAIR ARMIJO: It's a pretty dramatic thermal shock, but it didn't have the loading that you necessarily would have in a fuel assembly and everything else. But it's comforting to know it doesn't shatter.

MS. FLANAGAN: Yes.

VICE CHAIR ARMIJO: But it doesn't say anything about the mechanical conditions in an assembly.

MS. FLANAGAN: Yes.

VICE CHAIR ARMIJO: But it's good to have that it didn't shatter. We'd have a different meeting.

MEMBER CORRADINI: So, you're only taking qualitative, warm feeling out of that. That's the way I interpreted -- you kept on saying that. But I only took it --

MS. FLANAGAN: The observation --

MEMBER CORRADINI: -- as a qualitative, warm feeling.

MS. FLANAGAN: Yes. The observation that that all samples survived quench is just that, qualitative, warm feeling.

VICE CHAIR ARMIJO: But then the other issue was when the ring-compression test -- all our focus is on ductility, measuring the strain, very small strain. In the three-point bend test our focus or acceptance is absorbed energy to fracture, or some strength measurement, but not a strain measurement. And if both are equivalent, why wouldn't we do a simple mechanical strength thing on the ring-compression test and find that acceptable, just to be consistent from the balloon region to the undeformed region?

MEMBER CORRADINI: Can I ask a slightly different question since we're --

VICE CHAIR ARMIJO: Okay.

MEMBER CORRADINI: So, you don't have to go back to the figure, but the figure where you basically had the bending moment and you had the various temperatures and such, I guess I take -- I was taking -- I was feeling good about it because the qualitative shape on how it changes with hydrogen content, or oxidation content was giving me confidence, and only the Studsvik's test where I actually had more of what I'll call a complete integral test and the overlay gave me the quantitative confidence. Right?

MS. FLANAGAN: The Argonne tests were complete integral in the sense that they are single rod and they were brought through the whole temperature. They just didn't have any fuel in them, but they had simulated fuel.

MEMBER CORRADINI: Right. But if I go through the Studsvik, your overlay -- it's not that graph. It's one of these graphs.

MS. FLANAGAN: This one?

MEMBER CORRADINI: Thank you, that one. That in the Studsvik test it was essentially a fuel rod.

MS. FLANAGAN: Yes.

MEMBER CORRADINI: Okay. So, I was looking at the shape all being identically the same. I wasn't hoping that they all had to lie on the same line.

MS. FLANAGAN: Right. In fact, we expect them --

MEMBER CORRADINI: That's what I guess I'm trying to get at.

MS. FLANAGAN: Yes, we expect them to lie on different lines --

MEMBER CORRADINI: Right.

MS. FLANAGAN: -- as a function of a hydrogen effect.

MEMBER CORRADINI: Right.

MS. FLANAGAN: So, if there was no hydrogen effect but only oxidation effect, we would have seen all of these points on the same line. And it would just show that the more oxidation you have, the less mechanical behavior you have. And in this case, the fact that they're on different lines is where we came to the conclusion that there is an impact of the hydrogen in the balloon region that degrades mechanical properties.

MEMBER CORRADINI: Okay.

VICE CHAIR ARMIJO: But it's still adequate. That's what you're concluding, it's still

-- what would your acceptance limit be if you were accepting on the basis of bending moment? Do you have a number, an idea there?

MEMBER CORRADINI: I remember I was asking her that at the Subcommittee meeting, and she had a great answer at the moment. I don't remember what it was.

VICE CHAIR ARMIJO: I don't remember the answer. Maybe Michelle can --

MS. FLANAGAN: I mean, we could say that in this scenario what we're saying is the values that we're observing at 17 percent are what we want to maintain. So, you could say -- I really don't want to go back --

MEMBER SHACK: Why you want to say --

(Laughter.)

MS. FLANAGAN: You know, a lot of the discussion here is really not new. I mean, the fact that the balloon region has been its own beast has been true since 1973. So, we're not trying to get -- we're really just trying to assure that what we're doing is appropriate, that we're not missing something in the balloon region, and that we continue to have an understanding of the effects of hydrogen, the effects of burnup, and the effects of oxidation. So, that's where we're -- that's our objective with this.

VICE CHAIR ARMIJO: Okay.

MS. FLANAGAN: And some of the things that we're dealing with have been there since this rulemaking was first initiated in the `70s.

VICE CHAIR ARMIJO: Michelle, could you go back to your Slide 20?

MS. FLANAGAN: Yes.

VICE CHAIR ARMIJO: Would you explain those two data points, the brown that's at zero maximum energy, and the red data point?

MS. FLANAGAN: Yes. So, these are pre-hydrided samples, so particularly the brown one had a hydrogen content of almost 700 weight ppm. And when the sample was brought through a LOCA transient, and then tested in four-point bending, the measured failure energy was very low.

VICE CHAIR ARMIJO: Okay. So, it just went up to the elastic range, and broke. There was no area under the curve or something.

MS. FLANAGAN: Yes. And I don't think this value is zero, actually. I have to have the table with me --

VICE CHAIR ARMIJO: Pretty close.

MS. FLANAGAN: -- but it's very close to

zero.

VICE CHAIR ARMIJO: Okay. But the irradiated high-burnup ZIRLO was still the order of a unit of .5 to 1 or something on your scale.

MS. FLANAGAN: Yes.

VICE CHAIR ARMIJO: And those were about 200 ppm hydrogen.

MS. FLANAGAN: Yes.

VICE CHAIR ARMIJO: Okay. I understand the chart. Thanks.

All right. Any other questions?

MEMBER POWERS: One question, somewhat afield, but one that gets asked to me frequently, and I don't know that you can best -- but I continue to see things coming out of France worrying about collapse of fuel fines into the ballooned region, and it's effect on the long-term coolability. Are you in your program looking at that, or is that on the to-do list, or something like that?

MS. FLANAGAN: Relocation is definitely an element of what research is investigating, what the Office of Research is investigating. It's not reflected in this report, and it's not part of the mechanical behavior; however, it is a subject that we are --

MEMBER POWERS: Thinking about doing something with.

MS. FLANAGAN: Yes.

MEMBER POWERS: Come tell us when you've got something to tell us.

MS. FLANAGAN: Yes. We certainly will.

VICE CHAIR ARMIJO: Okay. If no other questions, I guess we can turn it over to EPRI.

(Off the record comments.)

MR. YUEH: Good morning. My name is Ken Yueh. I'm Project Manager with Electric Power Research Institute. I just have very brief comments, all of our feedback to the mechanical evaluation of the ballooned and ruptured region.

The industry in the past has proposed to use some similar to disposition to whole rod. That's a big area and, therefore, we're fully supportive of the research conducted by the NRC.

I do want to make a comment what was discussed a little bit earlier about the forces that are not known, the fuel is expected to experience post LOCA. People are looking at that. The Japanese working with the Strand system that much about the requirement would expect from real fuel geometry in terms of these strains that you would experience. And others have done the quench test where they have oxidized fuel clad within a grid, and then they quench the grid. Okay? The fuel rod -- the fuel tube stayed in tact, so it's I think something definable. And I want to say this because the industry is interested in looking at an alternative to the ring-compression test.

As the Vice Chairman alluded earlier, the balloon region is the weakest spot, and the rest of the clad is based on some other test data, has shown at least equal strength compared to the balloon region.

What I'm going to present is data generated by both Argonne National Lab and the Japanese, and the results they reported I think are consistent with what NRC just generated. And that the quench survivability, people agree with that.

VICE CHAIR ARMIJO: Ken, could you speak up a little bit louder? It's very hard for us to -- at least for me to hear.

MR. YUEH: Okay. Then the mechanical strength, the degradation of mechanical strength, at least some of the test data is showing there is some dependence initially, but that dependence decreases with both load and ECR. But a lot of the efforts by other international groups, they're more interested in defining a way to disposition the whole rod, and not necessarily using ductility as a means to demonstrate compliance with coolability.

I showed these two slides at the Subcommittee meeting. It is a plot of I think LOCA integral test as part of 1/T, which is high temperature -- shown in this dashed line 1,200 degrees Celsius and the time of oxidation. What this chart is showing, the red, the samples have failed during quench. So there's a lot of space between the 17 percent limit and 1,200 degrees in the sample that failed still particular margin.

And then on the right-hand side where we show a closer plot as 1/T showing the samples that survived the impact test that absorbed .3 joules of energy. And within this plot shows different populations of different hydrogen concentrations, so you have hydrogen -- this is the hydrogen pickup that joined the LOCA oxidation, so this was not pre-hydrided. So, above and below the burst you have two minutes of a lot of hydrogen. So, we group that into three different groups, less than 300 ppm, 300-600, and greater than 600. The high samples with hydrogen reached almost 2000 ppm.

Now, the data is uniformly mixed so there does not appear to be any trend in terms of energy absorption capability as a function of hydrogen pickup.

MEMBER SHACK: But that doesn't include any -- I mean, there was no pre-hydriding in this --

MR. YUEH: In the next slide I will show some of the Japanese results. And we discussed that at the last meeting about the Japanese test, whether it's a go/no-go test. But they actually did record the load from the quench.

This shows the sum of the Japanese test results. This dashed line here is irradiated Zircaloy-4 but hydrogen pre-charged. There's a lot of hydrogen there. In that test, they restrained the system. Post-LOCA when -- during the flooding phase, they restrained the sample to maximum load of 540 newtons on the sample. Now, this is generated based on the 540 newtons. This is where below the line the sample survived, above the line the sample failed.

I want to add, I have a paper here I did not show. I just took this chart directly from the paper, from their presentation. I do have a paper here that shows the line -- if the load is increased, the line moves down a little bit. As the line moves down a little bit, the slope decreases. So, if the system is fully restrained, the sample is allowed to go to the maximum stress, there's almost no hydrogen-dependence.

VICE CHAIR ARMIJO: Well, Ken, you've got an awful lot of data there, and --

MR. YUEH: Yes, I won't go --

VICE CHAIR ARMIJO: All of the arguments of --

MR. YUEH: So, this is based on non-irradiated Zircaloy-4 that's been precharged.

VICE CHAIR ARMIJO: Okay.

MR. YUEH: All right. This is the train there.

VICE CHAIR ARMIJO: And that's from the Japanese test setup.

MR. YUEH: That's the Japanese test.

VICE CHAIR ARMIJO: Okay.

MR. YUEH: Now, the other data point boxes are high-burnup multiple alloys. I think they had MDA, ZIRLO, and MFI-1. I'm not sure what it is, multiple alloys. So, the open boxes are the samples that survived the test. So, initially they targeted 540 newtons, but some of the samples did not reach -- the stress did not reach that high, so the load was never reached. Shown on some of them, two of the samples that one with ON, these were not restrained. The ends were loose. The other ones were restrained, and then this one, the actual stress that's given here is less than 400 newtons. This one is 350. Some of the other ones they actually recorded the maximum load on the sample.

VICE CHAIR ARMIJO: Okay. I'm still catching up. On the data points labeled ZR-2, ZRT-1.

MR. YUEH: These are different --

VICE CHAIR ARMIJO: Are those irradiated?

MR. YUEH: These are all irradiated.

VICE CHAIR ARMIJO: Irradiated.

MR. YUEH: Box is all irradiated.

VICE CHAIR ARMIJO: How much hydrogen did they have in --

MR. YUEH: It's plotted as function of hydrogen --

VICE CHAIR ARMIJO: Okay. There is hydrogen going up. Okay. You're all irradiated, and they all survived.

MR. YUEH: And the burnup was on the order of 70. It's a little bit less than above this scatter. It's pretty high burnup.

Okay. One sample survived, and one sample failed, but reached 38 percent ECR. And their conclusion is the factor bunch and it's now reduced significantly by high-burnup and use of new alloys. And they do acknowledge that with non-irradiated material, there's an initial decrease in the fracture. But that decrease as the stress, as amount of load, restraint you apply to it is increased that dependence almost disappears.

VICE CHAIR ARMIJO: Okay. Well, it seems somewhere along the line that these data sets, the ring-compression data where we're measuring very small amounts of residual ductility, and these mechanical property tests, all the variables are addressed. Somewhere somebody should try and put this together and make a meaningful explanation of what is really going on, and what's -- the implication is you have a lot of margin.

MR. YUEH: Yes.

VICE CHAIR ARMIJO: That's what you're saying.

MR. YUEH: Yes, and I did --

VICE CHAIR ARMIJO: The ring-compression test, you're measuring very small amounts of strain, so it's a very difficult test to do. Makes you worry whether you have enough margin or not.

MR. YUEH: Well, I do want to show that -- your point here. This is the -- what's proposed for the ring-compression test, and if we reduce this line, let's say NRC has some threshold here, if we move the line down to that threshold, it is a tremendous amount of margin still compared to the ring-compression test. So, that's a point I want to make. And support one of the recommendations we have on my next slide.

VICE CHAIR ARMIJO: Okay. Keep going.

MEMBER SHACK: Is the 15 percent the actual Japanese regulatory limit, or is that somebody's proposal?

MR. YUEH: That's their regulatory limit.

MEMBER SHACK: Okay.

VICE CHAIR ARMIJO: Okay, keep going.

MR. YUEH: This is what I --

MEMBER CORRADINI: Can you go back? We're debating privately, so maybe we'll just make it public. So, I'm trying to understand what -- so, Sam basically said it best, which is you've got this data over here, and somehow I'm looking for some sort of interpretation.

VICE CHAIR ARMIJO: Yes.

MEMBER CORRADINI: So, if I'm understanding, since this is like the third time I've heard this in various forms, are you basically saying it's the pre-hydriding experimental technique that is biasing the data that we're seeing? I'm trying to understand what -- and maybe you said it, and I just don't get it.

MR. YUEH: It's a different metric. One is based on ductility, the other one is based on strength.

MS. FLANAGAN: Can I interject something? It's also looking at margin from a different perspective. We look at quench when we do a mechanical test afterwards, and we see what mechanical properties are left. And another approach would be to crank up oxidation until quench alone fractures the material. And then there's an additional load on these tests. So, it's like a different perspective on what margin means. It's in terms of oxidation, or it's in terms of mechanical behavior. Does that make sense? How far away am I? How come --

VICE CHAIR ARMIJO: I've still got to think of how this all comes together, because as metallurgists, we love ductility. I mean, how can you argue, if you have a ductile material, that's great. But it's very hard to measure when you're down in these -- in the dirt of the measurement of around 1 percent, you start getting nervous that you're kidding yourself. But these measurements on irradiated cladding under constraint with high hydrogen concentrations indicate you've got a lot of mechanical margin in some way.

MR. YUEH: Yes.

VICE CHAIR ARMIJO: And I'd like to see how this all -- it must all come together, because it's the same -- and I don't understand it yet, but --

MR. YUEH: Yes, it's approaching from different methods, to find a way to reconcile the difference, or try to make sense might be a little bit difficult. But I -- one thing I forgot to state earlier is the 540 newtons used in the Japanese test, people actually have done real test, and the actual measure load is on the order of 170-200 newtons. And they want to be conservative. They're stuck with earlier evaluation, which shows 540 newtons, so it's even another conservatism.

VICE CHAIR ARMIJO: And all of these are just pure axial loads, no bending loads or anything like that?

MR. YUEH: Axial --

VICE CHAIR ARMIJO: Okay. I've got to read that paper again. Those are the Nagase papers?

MR. YUEH: Yes, I have a copy of it here.

VICE CHAIR ARMIJO: Yes, I've got one. Thank you.

MR. YUEH: You've got one. Okay.

MEMBER BROWN: For the really simple-minded, me, I listened to both sides, and I'm just having a hard time similar to your comment; how do you bring these together? I mean, I look at this and it says based on your 540 newtons, and I may state this incorrectly, so fix me. Is that you've got all these hydrogen -- you've got all these hydrogen concentration samples and you loaded them to 540 newtons, and didn't --

MR. YUEH: What they have done is, it's a LOCA integral test.

(Simultaneous speech.)

MEMBER BROWN: -- where they failed at the upper and lower points?

MR. YUEH: That's right. It's fixed in place, and during the quench the amount of load applied -- as the sample --

(Simultaneous speech.)

MR. YUEH: The sample shrinks due to cooling.

MEMBER BROWN: Okay.

MR. YUEH: So, it's restrained, and the maximum load that the test parameter allows is 540 newtons. So, if the load is actually -- if actually the sample shrinks --

MEMBER BROWN: Pull that apart.

MR. YUEH: Yes, if it shrinks more, then the system relax a little bit, but keep the load at 540 newtons.

MEMBER BROWN: And they did not break.

MR. YUEH: They did not break, no.

MEMBER SHACK: Okay. But then you come to Dr. Powers' questions sort of in spades, is that you really have to be sure that your test is prototypical and limiting, and that you've counted for all the loads that you might want to account for; whereas, with the ductility you, in fact, have margin to account for -- should that 540 having a plus or minus uncertainty on it, that takes into account everything that might not be prototypical about your test.

MEMBER BROWN: Well, but his comment was that the maximum loads they saw were substantially less than the 540 --

MEMBER SHACK: It's not guarantee didn't do a LOCA.

MR. YUEH: It's not refuel, it's obviously the --

MEMBER BROWN: Well, neither of them --

(Simultaneous speech.)

MEMBER BROWN: Right, neither one of them, so --

MEMBER CORRADINI: But on the other hand, though, the argument would be -- at least to answer Dana's point, the argument would be with when you're doing it based on I'll just say the dark red line versus the dashed line, you're basing it on a sense that since it's not prototypic, you have margin, unmeasured but knowable -- but margin there.

MEMBER BROWN: Right.

VICE CHAIR ARMIJO: And keep in mind, we're still looking for coolable geometry, and all of this stuff is saying this stuff isn't going to fall apart. You're going to still have something that looks like a fuel assembly when you're finished. And the question, to me, is what's the best way to measure it that gives you the most confidence, and is most reliable. And I -- the only thing makes me uncomfortable about the ring-compression test is we're measuring numbers down in the dirt, and that's hard to measure. And I just worry that I don't -- haven't seen the --

MEMBER SHACK: It is clearly giving you more conservative results.

VICE CHAIR ARMIJO: Well, yes, it's conservative, but it may be --

MEMBER SHACK: I mean, if you have margin, Sam, that --

VICE CHAIR ARMIJO: No, but it may be unrealistic. You might be getting stuff that's measured zero that has -- in fact, it's perfectly good material for the application.

MEMBER POWERS: Not after this, it's not perfect.

(Laughter.)

VICE CHAIR ARMIJO: No, I mean adequate, adequate. Okay, Ken, go ahead.

MR. YUEH: So, to summarize, I made this point at the last meeting, because the draft rule is about meeting ductility, and balloon region at least in the range we have a lot of hydrogen there is no ductility, so there's a conflict. And because the rule is the law, that we recommend that the ductility requirements be placed in the regulatory guides.

And then the second point is what Dr. Armijo -- I think his similar thought about if it's acceptable to the balloon region, why would the rest of the rod be concerned? And our position is because it appears that the clad does not decay from -- degrade at the same rate as ductility in terms of strength. You know, there's probably no margin if we use the strength-based metric. I think that's all I have. Thank you.

VICE CHAIR ARMIJO: Okay. Any comments, questions?

(No response.)

VICE CHAIR ARMIJO: With that, I'd like to thank the Staff and EPRI for -- I guess I could ask if there's any questions from the people in the room.

(No response.)

VICE CHAIR ARMIJO: Okay. So, thank you very much. We're ahead of schedule.

CHAIRMAN ABDEL-KHALIK: Thank you. We are 45 minutes ahead of schedule.

VICE CHAIR ARMIJO: Thank you very much.

MR. YUEH: Thanks so much.

CHAIRMAN ABDEL-KHALIK: We're off the record.

VICE CHAIR ARMIJO: Okay, thank you.

(Whereupon, the proceedings went off the record at 12:00 p.m., and went back on the record at 1:43 p.m.)

A-F-T-E-R-N-O-O-N S-E-S-S-I-O-N

(1:43 p.m.)

CHAIRMAN ABDEL-KHALIK: We are back in session.

At this time, we will move to Item Number 4 on the agenda, Technical Basis and Rulemaking Language Associated with Low-Level Waste Disposal Site-Specific Analysis. And Dr. Ryan will lead us through the discussion.

MEMBER RYAN: Thank you, Mr. Chairman. This is one of two Subcommittee meetings that we will have -- one now, one in August I guess is the rough schedule -- and then we are planning for a letter in September aggregating our information gathering from the previous Subcommittee, the two upcoming Subcommittees, and the full Committee input.

So I would appreciate it if members would advise me of any opinions or thoughts or any kind of input they want to provide from this meeting in preparation for the next Subcommittee meeting and then the followup letter in September with the full Committee.

So with that introduction, I will turn to Andrew Carrera from FSME, who is going to open the session for us. Andrew?

MR. CARRERA: Yes. Thank you, Dr. Ryan. Good afternoon. My name is Andrew Carrera, and I'm the Project Manager for the Part 61 site-specific analysis rulemaking. And before I begin, I would like to thank the members and staff of the ACRS for giving us the opportunity to present our rulemaking and technical basis to you today.

First, I will briefly go over the reason why we are conducting this particular rulemaking and then go over the proposed changes that the staff has made to the proposed rule language. And then, Dave will follow me with his presentation on the technical basis of this rulemaking, and then I will come back and briefly go over the stakeholders' comments that we received on the preliminary proposed rule language.

Next slide, please.

Now, as you may be aware, when the original Part 61 regulations were developed, there was a set of conditions that were analyzed by the staff at that time. These include certain existing defined volumes and concentrations of radioactive waste. However, those conditions are changing, and low-level waste disposal facilities are facing -- are currently faced with disposing of waste types and quantities that were not considered at that time.

And one significant parameter that was considered but ultimately did not make its way into the Part 61 was uranium, and particularly large quantities of depleted uranium. And I'll refer to it as DU from now on.

The quantities of DU that were considered during the original Part 61 development were much, much smaller than the challenges that we are facing with today, and that is one of the cornerstone why we are conducting this particular rulemaking.

MEMBER RYAN: Andrew, just for my own benefit, if you could explain a little bit -- one million metric tons sounds like a lot, but most wastes are measured in volume. I would really like to know what the volume of this million metric tons is. Maybe not right this second, but if we could hear it in those terms, that might be a helpful comparative for us.

The other part of that is a lot of DU I know is metal, and I would be curious as to how much of that million metric tons was metal versus some other form that might be more mobile in the environment.

MR. ESH: The quantity -- this is Dave Esh. The quantity is fairly large, too. I mean, at a metric ton, you're talking about a thousand kilograms per metric ton, and the density that is in powdered form, you're talking about a powder packed inside a barrel is packed inside a facility.

My guess is it probably works out to be somewhere around four to five thousand kilograms per cubic meter, so -- density. So you can -- if you wanted to convert this to cubic meters, it's quite a few cubic meters. Just a rough guess.

MEMBER RYAN: Okay. That's fine. That's helpful. Thank you.

MEMBER BLEY: And one cubic meter is probably a couple of barrels? I'm just --

MR. ESH: Yes. A barrel I think I estimated before would be maybe like a half a metric ton, something like that.

MEMBER BLEY: And so a couple of barrels --

MR. ESH: Yes.

MEMBER BLEY: Per ton.

MR. ESH: I'm getting older, though, and my memory is, you know, so --

MEMBER BLEY: It will get worse.

(Laughter.)

MR. ESH: We could give you a better

number, but for context that's --

MEMBER BLEY: All I wanted was context.

MEMBER RYAN: People sometimes work in volume and weight, and it would be helpful to have an answer to that question.

MR. ESH: Well, the material, as it's generated, is usually in some fluoride form, but we don't think the fluoride forms are at all acceptable for disposal. So the concept is that you will convert the fluoride forms probably to an oxide, which is more stable for disposal, so your question about what the form of it is, we expect most of this material should be oxide.

MEMBER RYAN: And there are some -- there is some DU metal that is disposed as well.

MR. ESH: There is DU metal that is disposed, too.

MEMBER RYAN: A component of --

MR. ESH: When you're dealing with metals, if it's a big block or ingot of metal, that's one thing, but if you -- say you are dealing with uranium shavings, and you start worrying about pyroforicity --

MEMBER RYAN: Yes.

MR. ESH: -- and other things, too, so --

MEMBER RYAN: A lot of it these days is

intact pieces and parts.

MR. ESH: Yes.

MEMBER RYAN: All right. Thank you. Sorry for the interruption, Andrew.

MR. CARRERA: Thank you, Dr. Ryan. And there would also be significant changes in the ways in which the nuclear power industry managed their waste, and the emergence of a concept known as blending. And blending is when you take Class B and Class C waste and blend them with Class A waste to lower the waste classification, and then dispose them as Class A waste. And blended waste were also not considered in the original development of Part 61 regulations.

MEMBER BLEY: I don't deal with this stuff every day. Remind me what the classes are, and what classes do you --

MR. CARRERA: DU, by default, is a Class A waste. And there are three classes of waste of A, B, and C, and their designation is based on how --

MR. ESH: The three waste classifications -- A, B, and C. A is -- in concept is supposed to decay to levels that don't pose a risk to an intruder at 100 years. So after 100 years somebody could dig into it and not have an exposure above what is intended.

Class C waste is intended to meet that general concept at 500 years, so Class C waste, for Class C waste there is a requirement that you either have to have an intruder barrier that lasts for 500 years, or you have to dispose of it at least five meters deep. And B is in between. It's -- has waste stability requirements associated with it, I believe, of 300 years.

But the general framework for low-level waste was we'll take -- mainly dealing with shorter lived waste, things that are dominated by the cobalt-60s and the strontium-90s and cesium-137s of the world. And we'll make a framework that we can put those into, so that as they decay over time we manage the risk through our regulatory framework and our technical requirement.

For depleted uranium, we had this other box in the regulation. We'll talk about it as 61.55(a)(6) is how we'll refer to it, which when they wrote the regulation they basically said anything that doesn't fall into the other boxes is Class A by default.

Well, uranium didn't fall into the other boxes, so it's Class A. But a legal interpretation of the regulation is that it's Class A. Technically, whether that's right or not, I would say probably not. But legally that's the decision.

MEMBER SIEBER: And the activity actually increases over time.

MR. ESH: Yes. So there is a --

MEMBER SIEBER: Doubles.

MR. ESH: -- there is two tables in the regulations that define the waste classification, and Table 1 has the long-lived isotopes. And to be Class A, you have to be basically one-tenth of the concentrations that are provided in Table 1. To be Class C, you have to be at or below the concentrations in Table 1.

So there are long-lived isotopes that are disposed of as low-level waste, but the analysis was designed to limit the concentrations that you would have of the long-lived waste that goes into the system.

MEMBER BLEY: And all three classes are low-level waste.

MR. ESH: All three classes are low-level waste. That's correct.

MR. CARRERA: Thank you. Next slide, please.

MEMBER RYAN: Sorry, Andrew. We've got a

comment.

MR. McKINNEY: Chris McKinney, Performance Assessment Branch for NRC. I just want to clarify that we actually have a fourth class of low-level waste, which is greater than Class C waste, which is a federal responsibility and isn't disposed of currently under the commercial -- at commercial sites. But there is --

MEMBER RYAN: It is disposed at DOE facilities.

MR. McKINNEY: Right. But there is DOE-like material that is disposed of. It is, again, not -- they don't use our classification system.

MEMBER RYAN: Okay.

MR. McKINNEY: But there is a fourth class that we don't discuss much, but it is part of low-level waste, so low-level waste is A, B, C, and greater than Class C.

MEMBER RYAN: I think one member's benefit -- and it's a point that I think about a lot -- is that none of this is quantity driven. It's all concentration driven. So a very small amount of greater than Class C waste might be something you could put in your pocket, but it's still greater than Class C and unacceptable for disposal as low-level waste, and vice versa.

VICE CHAIRMAN ARMIJO: What is the nuclear medicine waste? Is that in this category of low-level waste that comes out of --

MR. CARRERA: Yes, it's -- it depends on where it -- where the low-level waste classification --

MEMBER BLEY: It could be any of the three?

MR. ESH: It could be, yes.

MEMBER RYAN: I guess it's -- I think it's fair to say -- and correct me if I'm wrong, Andrew or David -- but most radionuclides used in medicine are, by their nature and requirement, short-lived. Some of the generators, like the molybdenum generators from which tech-99 comes from, is a longer-lived radionuclide.

So it's not all just the short-lived stuff, but the quantity -- whether it's 2- to 300 curies nationwide of that stuff is relatively small compared to, say, what the nuclear power industry generates. So it's not a huge burden --

VICE CHAIRMAN ARMIJO: So it's not much --

MEMBER RYAN: -- to deal with.

VICE CHAIRMAN ARMIJO: -- of a contributor to this issue.

MR. ESH: No. All of the what I would call in our context very short-lived -- you know, we have -- in low-level waste, our framework has a 100-year institutional control period. So anything five years and below, it's really hard to show up. So it basically all decays in place. So all of the very short isotopes associated with medical waste would fall into that description.

MR. CARRERA: Okay. I'll just continue. The Commission is aware of these issues and has been working with the staff to address them. And as a result, and in a staff requirement memorandum, SRM, to SECY-08-01447, the Commission directed the staff to proceed forward with a limited scope rulemaking to Part 61 to require low-level waste disposal facilities to conduct site-specific analysis prior to the disposal of significant quantities of depleted uranium, and to develop technical guidance for conducting these analyses.

And in a subsequent SRM, the Commission directed staff to incorporate blended waste into the existing rulemaking for depleted uranium. So the site-specific analysis rulemaking we are talking about today covers both of these emerging issues.

Next slide, please.

And with the Commission direction in mind, the staff developed a technical basis document to support this rulemaking. A multi-disciplinary rulemaking team was formed, and the rulemaking process started in October 2010. The staff developed the objectives and purpose of the proposed rule, and that is to specify site-specific analysis requirements for low-level waste disposal facilities to demonstrate compliance with the performance objectives in Part 61.

And these site-specific analyses are listed here -- performance assessments, which would be included in Section 61.41; intruder assessments, which would be included in Section 61.42; and long-term analysis, which would be included in a newly proposed section, Section 61.13(e); and number 4, updated analysis.

I have Section 61.13(e) on the screen, but actually it's 61.28 and 61.52, which is correct on your handouts.

And these analyses would enhance the safe disposal of low-level waste and would also identify any additional measures that would be prudent to implement. And I will go into greater details of each of these analysis requirements in a moment.

VICE CHAIRMAN ARMIJO: So you are going to cover for each of those --

MR. CARRERA: Yes, sir.

VICE CHAIRMAN ARMIJO: -- including the intruder stuff, because I'd like to look -- understand more about that particular --

MR. CARRERA: Yes.

VICE CHAIRMAN ARMIJO: Requirement.

MR. CARRERA: And we have talked to the technical basis of why the staff chose to include intruder assessment and the requirement in its technical talk.

Next slide, please.

And the staff also proposed additional amendments to the current Part 61 regulations to facilitate the implementation and to better align the requirements for the current health and safety standards.

In addition, when it developed Part 61 regulation, the NRC considers potential doses to an offsite member of the public and an inadvertent intruder based on certain assumptions regarding the type of waste that was likely to be found in a commercial low-level waste disposal facility.

As mentioned before, large quantities of depleted uranium and blended waste were not included in the technical basis, because they were not envisioned to be a major candidate for disposal at the Part 61 facility.

Recently, these waste streams have become candidates for disposal, which necessitates this particular rulemaking. And the staff was concerned that there may be other previously unanalyzed waste streams that will also become candidates for disposal at the Part 61 disposal facilities in the future, and would, therefore, require other rulemaking like this.

So, and the staff considered a number of options in development of this proposed rule, and the staff decided that an amendment that requires site-specific analysis for all types of waste would be the most comprehensive approach.

MEMBER BLEY: I'm trying to come to grips with something I suspect is a legal statement rather than a technical one, but I'm not positive. You said the reason you need the rulemaking is because you hadn't envisioned that you would be in a Part 61 waste facility, but do use in some kinds of waste facilities already, right? It's just that they weren't called Part 61, because Part 61 didn't deal with DU. Am I right on that?

MR. ESH: Yes. I think the answer --

MEMBER BLEY: There's a lot of it around, I think, right?

MR. ESH: I think the answer is that it is in various types of facilities, and there -- as some of our licensees like to remind us, there are exemption criteria that allow you to determine certain material as exempt, too. And you can dispose of DU counterweights in facilities right now, because they're exempt. So --

VICE CHAIRMAN ARMIJO: Is that because they're metal, metal form, or if --

MR. ESH: That's part of the issue here is I think, you know, we'll talk about quantities and concentrations and those sorts of things, but you also have to really think about form. There is a big difference between when you are disposing of something with a very high surface area to volume ratio, like a powder, and you are disposing of a big block of metal. Those pose --

VICE CHAIRMAN ARMIJO: Yes.

MR. ESH: -- two different dispersibility risks to people or the environment, but we're dealing with a lot more of the latter, not the former.

VICE CHAIRMAN ARMIJO: Okay. But I wanted to get at the issue. Is there a preferred depleted uranium? Does the staff identify a preferred form like metallic big box? Would it be an ideal form?

MR. ESH: Well, I'll walk through --

VICE CHAIRMAN ARMIJO: Okay.

MR. ESH: -- the technical aspects of the problem, and then we can talk about that at the end. My background before coming to NRC was in waste form development, and I think when you are going out to longer times you much more need to focus on the material science aspects of the problem and less on some of the other things that are more common in traditional facilities.

So you have to think really hard about what's the form that I'm going to dispose of. We are generally in the position that we don't demand or dictate a particular form, but we try to give information to say, "If you want to develop a form, here are the steps you should go through to determine whether that is appropriate or not."

So it's up to a licensee to propose, okay, I want to make a glass ceramic with the depleted uranium in it, or I want to make concrete with depleted uranium in it, or I just want to put it in in the powdered form and try to demonstrate what the risks are associated with that.

VICE CHAIRMAN ARMIJO: But right now, if somebody had a lot of metallic uranium, they could go the exemption route.

MR. ESH: Well, if it's counterweight.

VICE CHAIRMAN ARMIJO: If it's counterweight.

MR. ESH: If it's a specific -- if it's boxed out of the specific type of material. But no, otherwise, it would be a waste stream just like -- just like some other form, some other physical form.

MEMBER BLEY: Just one last question from me before you go on and give us the details. Does NRC regulate chemical toxicity or just radiotoxicity?

MR. ESH: Just radiological toxicity.

MEMBER BLEY: Go ahead.

MR. ESH: EPA regulates chemical toxicity.

MEMBER RYAN: Sam, I would also offer to you to think about it's not only the waste form, it's the waste package, the disposal technology, the cover technology, an entire system working together to confine and contain whatever the material is, not just the waste form. Although the waste form is an important one, I think it's helpful to think about it as a system rather than as one element by itself.

MR. ESH: It's very analogous to a reactor system that has multiple safety components --

MEMBER RYAN: Sure.

MR. ESH: -- or defense in depth and all things that you try to put in place to mitigate the risk. The waste disposal systems have the same sort of features. They're different and they're much more passive and much less active, so --

MR. CARRERA: Next slide, please.

Now I'll go into the details of the site-specific analysis requirements, and let's start with the performance assessment in Section 61.41.

Part 61 currently requires licensees to prepare an analysis to demonstrate that the low-level waste disposal facility meets the requirement in Section 61.41, and that is to ensure the protection of the general population from releases of radioactivity.

This analysis is currently called a technical analysis, instead of a performance assessment, and does not contain a period of performance associated with the analysis.

The staff proposed revision to this section to include specifically the use of the term "performance assessment," and also the use of the TEDE dose methodology, so that the Part 61 regulation will be consistent with the radiation protection standard in Part 20.

The proposed rule would also specify a newly defined period of performance of 20,000 years for the performance assessment.

Now, Dave will talk later in his technical presentation of the staff's basis for recommending the 20,000 years period of performance.

Next slide, please.

And intruder assessment -- again, Part 61 currently does not require a licensee to perform an intruder dose assessment to demonstrate compliance with Section 61.42, which is for the protection of an inadvertent intruder.

VICE CHAIRMAN ARMIJO: Why do you have to protect -- set these broad, broad rules to protect isolated intruders that are really a hypothetical assumption? Where do you get the obligation to protect this person?

MR. ESH: That's a good question. When Part 61 was developed, they -- we aren't adding this performance objective.

VICE CHAIRMAN ARMIJO: Well, I understand it's there.

MR. ESH: The performance objective is

there, and it's partly there because when the regulation was developed it was around the time where some national events, such as Love Canal, happened, and there was this concept that, while we can provide some controls and restrictions to try to prevent access or use of the site in the future, that you can't all together prevent that over long periods of time, because you are relying on things like records and markers and institutional knowledge.

The NRC's policy and approach is not to have active maintenance or active control of the facility past the institutional control period. So when you go out over time, they thought, well, we need something to evaluate what happens if somebody accesses the site and inadvertently disturbs the site or contacts some of the material. That's where the performance objective was derived from.

It's not necessarily done in other fields, such as in the disposal of industrial metals, but it is done in the nuclear field pretty commonly throughout the world, not just in the U.S. but internationally it's done.

VICE CHAIRMAN ARMIJO: And this inadvertent intruder opens up this disposal site, and basically lives there continuously, and you are supposed to protect them?

MR. ESH: Possibly, yes. The waste classification tables -- the waste classification tables were developed assuming that somebody -- they looked at different scenarios, okay.

So they looked at scenarios of, well, what happens if somebody uses the site and digs into it, but the material is distinguishable from the -- they know they have waste, okay? We dug somewhere we shouldn't have dug, and we accessed material in the facility. That's called intruder discovery scenario.

But then, they also analyzed, what happens if the material isn't distinguishable from the material that they are digging into? What are the risks they are going to be exposed to? That was broken out into an acute intruder scenario and a chronic intruder scenario, so somebody that builds a house on the site, puts in a foundation, the guy that builds the house is the acute intruder, the person that lives in the house after the house is built is the chronic intruder.

VICE CHAIRMAN ARMIJO: And this applies out to 20,000 years for --

MR. ESH: Well, in the original analysis, it was done to -- it didn't have a timeframe associated with it. So it was done and the waste classification tables were derived from it using an inverse calculation. And I'll talk about it whenever we get to my presentation.

Right now, we're saying that NRC initially took the effort of deciding, well, we want to protect this intruder. It's a performance objective that was developed. There's two ways of going about that. NRC can either do the calculations and develop tables, which is the approach they took, or they could say, okay, each licensee do this calculation for your individual site, and you develop the concentrations that you can take.

They envisioned that there were going to be lots of low-level waste disposal facilities, so they opted to take the route of NRC will develop the tables and develop the concentrations, and those will apply to all facilities.

So that's kind of the history of where it came from, and we are within the scope of -- we are in a limited scope rulemaking. So to do something like to remove a performance objective would be maybe pushing the limits of what is expected in this limited scope rulemaking.

VICE CHAIRMAN ARMIJO: I think you should try.

MR. ESH: Yes.

VICE CHAIRMAN ARMIJO: I think to set these requirements for this hypothetical intruder 20,000 years from now, and protect him and, you know, the cost and the effort, is it really worth this?

MEMBER RYAN: Sam, and one other further protection that David hasn't touched on yet for the longer term is that back when the rule was first written there really weren't substantial institutional control funds at these sites.

And now there are in the tens of millions of dollars held, you know, specifically for the purpose of long-term monitoring and maintenance that were not there when the rule was written. So that's an added feature to current practice that is not reflected in the current rule.

And, you know, from my experience in monitoring and maintaining a site, $10 million is plenty of money to go a long time.

VICE CHAIRMAN ARMIJO: Well, it just seems like it's almost from the same category as general -- protection of the general population, which is the proper role. There's no question about that. But this isolated, hypothetical, individual, thousands of years into the future -- how can that make any sense?

MR. ESH: Let's defer maybe additional discussion until I -- because I have some slides to talk about in detail, and then we can revisit it.

VICE CHAIRMAN ARMIJO: Sure.

MR. ESH: All right.

VICE CHAIRMAN ARMIJO: I mean, it's a policy issue that's not -- that's not currently up for grabs is what you're saying.

MR. ESH: You're certainly free to make that comment.

(Laughter.)

VICE CHAIRMAN ARMIJO: Believe me, I will.

MR. CAMPER: Let me add a comment to this, if I might, please. Larry Camper, Director of Division of Waste Management, Environmental Protection. Around your question, I would point out that we have the assignment from the Commission -- we have three assignments from the Commission today around Part 61.

One was to conduct a limited rulemaking, which is what we're talking about today, which is to require the site-specific performance assessment focused around large quantities of depleted uranium.

Now, one interesting thing that has

occurred is that the working group has decided to make it apply to all radionuclides, not just large quantities of depleted uranium. That's because they heard that during public comment gathering, but, still, we would argue that that is consistent with the limited scope rulemaking.

The second assignment that we have is to risk-inform the waste classification scheme and look carefully at what is depleted uranium in that context.

And then, the third thing is to look at Part 61 more comprehensively. And what we decided to do was to go out and solicit public input, and so forth, and come back to the Commission with a recommendation in December. But the kinds of things that you're talking about -- this notion of, do we need to have an inadvertent intruder -- would be in that bigger policy look at Part 61. But we understand your point.

VICE CHAIRMAN ARMIJO: That's still within the scope of the direction you've been given. That's --

MR. CAMPER: No, it's not.

VICE CHAIRMAN ARMIJO: It's not.

MR. CAMPER: It's not.

MEMBER RYAN: I guess I want to make a

point on that, Sam, that it seems like it's backwards from that standpoint. If you're going to change the overarching policy, you probably ought to do that before you redo the regulation.

VICE CHAIRMAN ARMIJO: Okay.

MEMBER RYAN: I think that -- I think that's something for the Committee to think about is, are we out of order in terms of what it's best to do first.

VICE CHAIRMAN ARMIJO: Yes, priority.

MEMBER RYAN: Thank you, Larry.

MR. CARRERA: Yes. I think we discussed intruder assessment enough. Let's move on to the long-term analysis.

Staff has determined that it would be prudent to require additional long-term analysis to ensure that waste streams significantly different from those considered in Part 61's technical basis can be disposed of while still meeting the performance objectives in Part 61.

And the proposed long-term analysis, which would be added to a new section -- Section 61.13(e) -- will consider the uncertainties associated with the disposal of long-lived waste streams. This analysis is needed to determine whether limitation on the disposal of some long-lived waste streams at certain sites may be needed to ensure for the safe disposal.

This analysis will require consideration of peak annual dose that would occur 20,000 years or more after site closure. No dose limit would apply to the results of the analysis, but the analysis would need to be included as an indication of a long-term performance of the disposal facility.

VICE CHAIRMAN ARMIJO: Do you think it's actually practical that anybody could actually show you that they can guarantee that this facility would be functional for 20,000 years without any supervision, with it just abandoned in place?

MR. ESH: I think you have to understand the process of performance assessment, what it is intended to do, and what it can do, and what it can't do. It is intended to incorporate all significant uncertainties and reflect those in the output that you are generating to evaluate against a criteria.

And in some cases those uncertainties can be large and diverse. There are different things you can do to try to mitigate them, including engineering of your facility. But then you are talking about passive performance of engineering over very long periods of time. I think --

VICE CHAIRMAN ARMIJO: That's my point. That was the Yucca Mountain philosophy. And to demonstrate that this was possible, you could easily challenge every one of those demonstrations because of the uncertainties, and you wound up redesigning and overdesigning and overdesigning the overdesign, because --

MEMBER RYAN: Excuse me, Sam. I'm sorry to interrupt, but the -- I just got a note. The conference line is not open, and there are a number of people on the conference line.

Theron, can we open the conference line? Or, Derek, could you check and see if the conference line is open and -- or make it open? Hang on just a second, please.

(Pause.)

MEMBER RYAN: Okay. I understand the conference line is open. If you could all put your phones on the conference line in listen-only mode, that would be helpful.

VICE CHAIRMAN ARMIJO: Okay. Just to --

MEMBER RYAN: Thank you. I'm sorry, Sam. Excuse the interruption.

VICE CHAIRMAN ARMIJO: Just to go back, it just seems to me that having reviewed -- not as part of the ACRS, but in the university job -- the Yucca Mountain approach, it really couldn't converge. And one barrier after another didn't resolve -- didn't eliminate the challenges, because we're talking about times that are just so long -- I guess Yucca Mountain is now up to one million years.

I just think that these aren't really practical or achievable. So if you write a rule, it should be achievable, and so that somebody who said -- does the assessment can demonstrate it either by experience or test or geological history or something that says, "Hey, it's satisfactory."

MR. ESH: I would say that, at 20,000 years, you are certainly pushing the limits of what you can do with many engineered systems, in a near-surface environment in particular. But the performance assessment process is about looking at the engineered systems and the site -- the natural site conditions to evaluate how it's going to mitigate the risk from the facility.

The questions that you're asking are, what is your obligation as you go out in time to try to generate those impacts? And the answer can be that I don't think I have any obligation beyond a certain point in time, but that -- because of uncertainty, remember, low-level waste is the first step in the waste management train.

You don't have to dispose of material at low-level waste if you don't know what the impacts are and you think the uncertainties are too large. You can take that material and place it into deeper disposal, similar to what's done with transuranic waste or -- and geologic disposal.

The waste management system is designed to manage and mitigate uncertainties. And if you believe the uncertainties associated with an action are too large for near-surface disposal, then maybe you are not putting the material in the right box, is the argument I would say.

VICE CHAIRMAN ARMIJO: Well, you know, if the rules are set up that they can easily be challenged, and that you can't dispose of anything without enormous cost, then you haven't done your job. That's -- and that's what I worry, that when I see numbers like this, that you are pushing in the same direction that we got into with Yucca Mountain, and --

MR. ESH: I don't think you have an obligation, though, to make the problem easy if in fact it's not easy.

VICE CHAIRMAN ARMIJO: I'm not talking

about making anything easy. I'm talking about making it realistic.

MR. ESH: But if you don't set the criteria appropriately strictly, then everybody passes. And maybe it --

VICE CHAIRMAN ARMIJO: I'm not talking about that.

MR. ESH: -- maybe everybody shouldn't pass. I think you have to set the criteria appropriate for the problem, and then you determine who is going to pass and who is going to fail. I would argue that if I take only low concentrations of long-lived waste, or only short-lived waste, whether I set the period of performance at 10,000, 20,000, or 100,000 is not an issue at all.

I can demonstrate easily with technical analysis that I can limit the risk from that facility. So it's an issue of, when the problem becomes difficult, what should be your criteria for that difficult problem? We are in that box with this rulemaking.

VICE CHAIRMAN ARMIJO: Well, I've got to hear a little bit more about the specifics of the particular waste and the particular waste form. But it can't be one size fits all, and that's the impression I'm getting.

MR. ESH: Okay.

MEMBER RYAN: Sam, I'm sure -- Sam?

VICE CHAIRMAN ARMIJO: Yes.

MEMBER RYAN: We'll touch on that today some I'm sure, but maybe that's a topic for our next Subcommittee meeting. Or perhaps we could plan ahead and go into little bit more detail. Would you be okay with both of those solutions?

VICE CHAIRMAN ARMIJO: Sure.

MEMBER RYAN: And I guess I'm just trying to --

VICE CHAIRMAN ARMIJO: I'm trying to understand --

MEMBER RYAN: -- help shape it today, so that the next time we come we can have a full discussion on that topic, because I know, David, you have talked at some length about that with the Subcommittee, and it would be helpful to create that opportunity again.

VICE CHAIRMAN ARMIJO: You know, I think -- I read some documentation of Department of Energy practices, and they use a term of "reasonableness," which I think would be nice to hear in NRC stuff, in dealing with these things. And maybe you already feel you are being reasonable, but I will withhold judgment.

MEMBER RYAN: Chris?

MR. McKINNEY: On the reasonableness, it's already in our regulations in all of the performance objectives, a reasonable assurance. We have that strewn throughout Part 61 as it is, and we're talking mostly about the changes here.

Maybe for our next meeting we will focus definitely on how the structure of the rule came up in some other ones to put a little bit more on the context of the --

MEMBER RYAN: Anything specifically that addresses Dr. Armijo's concern and question, that would be helpful.

MR. McKINNEY: Right.

MEMBER RYAN: Thank you. Gentlemen?

MR. CARRERA: Next slide, please.

Updated site-specific analysis requirement. Currently, Section 61.28 and 61.52, which applies to disposal facility license closure program, do not have requirements for updated site-specific analysis.

The staff proposed revision to this section, to include requirement for this updated analysis, as part of the application process to amend the license for closure. And updated analysis requirement is needed to provide greater assurance of compliance with the performance objectives in Part 61.

MEMBER RYAN: Correct me if I'm wrong, but I think every site that exists today has some period, like 100 years or so, of committed institutional control and monitoring to help further the data analysis for that endpoint. I think that's a very important point, that there is a current funded capability at every one of these sites to do monitoring and maintenance and geohydrologic study and radiological analysis of samples, and all of that, for 100 years post-closure.

So just wanted to add that detail for the members' benefit.

MR. CARRERA: Thank you, Dr. Ryan.

And, finally, the staff also proposed additional amendments to the Part 61 regulation, such as adding new definitions or concepts as part of the program to facilitate the implementations of the site-specific analysis.

And that concludes my presentation on the preliminary proposed rule, and we can -- Dave will talk about the technical basis reporting of this rulemaking.

MR. ESH: Okay. A little bit of background about myself. I have worked in performance assessment for about 16 years on low-level waste, complex decommissioning sites, high-level waste, and waste incidental to reprocessing.

Prior to joining NRC, I worked at Argonne National Lab on treatment of sodium-bonded spent nuclear fuel and development of waste forms associated with that process. I'm going to talk to you today about the two key technical areas that we were faced with in this rulemaking and try to shed some light on where we ended up, where we did, and why.

The two main topics I'm going to cover are the intruder assessment and the period of performance. We also are in the process of developing a guidance document that goes along with the rule, that will be issued in parallel with the rule, that outlines the staff's position on what analyses to do and how to do it and things to consider -- a generic technical guidance document on low-level waste covering the rulemaking topics that we have here, and some additional areas where we felt additional guidance was needed.

Both of these areas I would argue are

important technical areas, given the Commission direction. As Andrew indicated, the Commission direction to us is to develop technical requirements necessary for the disposal of large quantities of depleted uranium and blended waste.

As I will talk about later in the presentation, I think the issue is a little more generic than that, even though they highlighted those two types of materials to fit into our low-level waste framework.

The technical requirements that are developed do provide a common framework for all licensees to be evaluated against. In low-level waste disposal, right now all of our facilities are located in Agreement States. So the Agreement States develop their regulations and apply it to the disposal of low-level waste.

So in the development of this regulation, we want to ensure that there is common requirements that are applied against all the Agreement States where there is -- when it's needed, when there's important requirements.

So the first area we will talk about is an intruder assessment. The intruder assessment has three parts. It has a waste classification and segregation requirements, intruder barrier requirements, and intruder dose assessment requirement.

The intruder assessment -- the first two parts are not new. They're in the existing regulation. Existing regulation has waste classification, segregation requirements, and intruder barrier requirements. As we talked about, there are three classes of waste. There are just different requirements for the different classes of waste.

What we have added in this rulemaking is the intruder dose assessment, and that is because the Commission directed us to not alter the waste classification system. So any material that is new, that wasn't analyzed in the EIS when Part 61 was developed, then would be outside of the tables potentially.

And the way that we thought, well, in this limited scope rulemaking that we could address that problem would be to have the licensees do an intruder dose assessment. That will capture any new material that is generated.

We were also sensitive to the fact, and consistent with the stakeholders that we heard from in the workshops in 2009, maybe in the past we weren't as smart as anticipating what low-level waste streams were going to look like today. Maybe we're not as smart today as what they are going to look like in the future either.

So this approach handles that. It allows it to adjust no matter what the waste that's generated. If you're doing this intruder dose assessment, that is essentially what NRC would do if we were going to revise the tables. We would revise the waste classification tables by doing an intruder dose assessment and calculating the concentration, which would give us a certain limit short --

MEMBER BLEY: And, again, I don't want you to answer this now. I just want to ask the question, because I don't -- didn't see where you are going to answer it when I skimmed through your slides. With respect to dose assessment for DU, when you get to the place you are going to talk about that, I would like to understand the kind of scenarios that are involved in getting to the doses that would be applicable here for individuals.

MR. ESH: Okay. Under the intruder assessment, the -- and the other part of it, or all of it? Okay.

MEMBER BLEY: Specifically, intruder

assessment, but I think it comes up elsewhere, too. So --

MR. ESH: Okay. All right. Yes. If I forget, remind me.

VICE CHAIRMAN ARMIJO: David, this is one intruder or a large group of intruders?

MR. ESH: It is envisioned to be an individual type of -- or, you know, a few people type of scenario. Okay?

One thing that I think was misunderstood by some of our stakeholders is the issue of intruder barriers, and they say, "Well, if you're applying this 20,000-year requirement to run for your intruder assessment, how are you going to demonstrate an intruder barrier for 20,000 years?"

We are not requiring a 20,000-year intruder barrier. The intruder barrier requirements are what they are for the three classes of waste. What we are saying is that if you can put in an intruder barrier, that you can justify its performance over whatever period of time you need it to perform, go right ahead and do that, provide the technical basis for it. But we don't have a requirement for an intruder barrier out to 20,000 years.

We have a requirement for meeting the

intruder dose assessment over this 20,000 years. And you can try to mitigate the impacts from that in whatever way you see fit.

And as we talked about, the reason for this is this waste classified under 61.55(a)(6) could represent an unanalyzed condition for this performance objective that is in the regulation. So as I talked about previously, the waste classification system was developed by the NRC staff, and it was done with this thought that, "Well, I have two ways to go about this problem. I can let licensees do this calculation or NRC can do the calculation and develop the concentrations that licensees need to meet to meet this requirement."

They chose to develop the concentrations and put them in Tables 1 and 2 in addition to the associated requirements in the regulation. And I think that was smart, because, as we have kind of talked about some here, beat around the bush on, you are dealing with future human behavior, and it's very uncertain.

So do you want that open to licensee interpretation and, therefore, you are going to have an awful lot of variability about how it's done? Or do you want to have some constraints to it about how it's done?

When NRC did the calculation, that provided some constraints to how it was done. It also, in some cases, did things that I would say aren't risk-informed, because it obligated you to analyze one type of condition. In the case of the development of the classification tables, it was done for a humid site, and that was applied to all sites, then, because all sites are bound to the concentrations in the tables.

So if you do allow somebody to do the intruder dose assessment, you have to be careful you don't get into speculation about the scenarios, open speculation about what's a credible scenario. But you also allow for some flexibility of considering actual site conditions.

So what is the natural conditions? Is it reasonable to put a house at a certain location? What's the persistent of those natural conditions over time? What is the current land use? How would you interpret the current land use of projecting into future land use? All those things come into play.

MEMBER RYAN: David, one element I have asked about before, and I think it's important to get a handle on it in this kind of conceptual development you are talking about is, when does an inadvertent intruder become an advertent intruder?

MR. ESH: Yes.

MEMBER RYAN: Then, you go from not knowing anything to knowing something that you ought to take action on. I think that's left completely unaddressed and needs to be addressed.

MR. ESH: Yes. Well, the difficult -- let me step back. The NRC, when they developed the regulation, they said, "We aren't protecting advertent intruders." So somebody that deliberately tries to go into a waste disposal facility, that is beyond what we should be required -- that is beyond what we will require people to protect against.

But the inadvertent intruder is somebody who doesn't know the material was there. And whether that's credible or not, you have to really step outside of the box and think about these long timeframes. And I would argue, especially engineers, we are subject to recency bias. So we think about what has happened in our lifetime, in the immediate lifetime, but how much that translates into, what is going to happen in 500 or 1,000 years? I think that is a very uncertain proposition.

And so we don't want to get locked around just because what is happening today makes sense, is that -- it's what is going to make sense over these very long time periods. And I would say, think about what has happened right here at Rockville over the last 250 years. Rockville looked a lot different 250 years ago than it does now.

And if you asked somebody 250 years ago whether they would have a 30-story high rise and iPhones and everything else, I don't think they would predict --

MEMBER RYAN: You are mixing apples and oranges. You know, the question isn't, what will we have 200 or 500 or 1,000 years from now. The question is, what can we recognize --

MR. ESH: Well, if we can --

MEMBER RYAN: -- 200 or 500 or 1,000 years from now.

MR. ESH: If the waste is recognizable, our guidance is go ahead and take credit that that waste is recognizable. That's more of a science and engineering program -- or problem. But when you're dealing with, what's the likelihood that somebody takes that action, there are lots of examples of people doing unintended things, including right down the road here in Spring Valley where they started digging up a bunch of mustard gas.

Just the other day I was reading --

MEMBER RYAN: But they stopped.

MR. ESH: But they stopped when they found it.

MEMBER RYAN: That's my point.

MR. ESH: But --

MEMBER RYAN: They became an advertent intruder when they recognized this wasn't what was expected.

MR. ESH: Well, they took actions to mitigate the risk.

MEMBER RYAN: And the regulation doesn't allow for that opportunity.

MR. ESH: They took actions to mitigate the risk, but over very long periods of time, what is your ability to recognize, is the issue. You're dealing with a lot softer problem than an engineering problem when you are talking about future human behavior.

MEMBER RYAN: I understand that part, but saying it is intractable and there is nothing we can offer to an inadvertent intruder becoming somehow an advertent intruder is not good either.

MR. ESH: Well, I don't know when -- I

don't think the scenarios and the behaviors that are -- that we are putting forth in the current rulemaking are extreme, irrational scenarios and behaviors.

MEMBER RYAN: I didn't say they were. I'm just simply saying you have left one aspect completely out.

MR. ESH: But I don't know how you credit something to protect health and safety when you don't know it.

MEMBER RYAN: "Don't know how" doesn't mean it's not a good idea that you address it.

MR. ESH: But how do you credit it?

MEMBER RYAN: I don't know. I mean, we'll have to think about that and work on that.

MR. ESH: If you have a recommendation of how you credit that, and you tell your stakeholders how you're crediting it, I --

MEMBER RYAN: I can give you several that you wouldn't --

MR. ESH: -- would be on board with that.

MEMBER RYAN: -- like, but I'll work on one you might like.

MR. ESH: I mean, I think we have -- you have to really think carefully about these timeframes, and what does your experience and our experience mean over the timeframes, because --

MEMBER RYAN: I agree.

MR. ESH: -- because I think there is a big difference when you are thinking 100 or 500 years and low-level waste associated with 100 or 500 years. I think you are on much stronger ground to credit current behaviors, what is the current land use, what is the likelihood of determining whether the material is recognizable.

On the hundreds of year timeframe, you are on much stronger footing crediting those things. On the thousands of year timeframe, I think you are on much weaker footing trying to credit those things.

VICE CHAIRMAN ARMIJO: So is it your assumption that the governments, society, will be equivalent to today, and will exist and will be functioning, but no more, no wiser, no more capable? Or is your assumption that at 10-, 20,000 years from now, there may not be a United States, there may not be a government, there are not -- we may be wandering around digging holes looking for food?

MR. ESH: The original developers of Part 61 envisioned this as an unlikely event, albeit possible. I think that's the language that was used in the regulation. I think we are generally in agreement with that.

It doesn't require societal failure for these things to occur. It requires you to not have persistent markers, records, government error, all the sorts of things that happen -- I mean, my dissertation was put on electronic media that I can't even read today, and that's not that long ago.

So you have -- there's a whole research area in the development of the persistence of records and markers and all that sort of -- it's kind of a softer feel, but I think that is where this comes into play. There is a lot of stakeholders that have that opinion and have that concern, and also, as I indicated, this was derived around a certain time when these sorts of things did happen on a pretty public scale, so --

MEMBER RYAN: Did you --

MEMBER BLEY: No, no, I was just hoping you could get through more of this before we run of out time, so I can understand it better.

(Laughter.)

MR. ESH: All right. So the intruder assessment, though, it is a regulatory construct. It is not a calculation of exactly what is going to happen in the future. It is a regulatory construct to provide some level of protection.

You could argue that it is too much protection, it's arbitrary, whatever. That is the construct. It's in the regulation. This is a limited rulemaking. We don't have much ability to eliminate a performance objective in the scope of this rulemaking.

MEMBER RYAN: So there's two points here, David. I think everybody appreciates, from your perspective, this is not in the scope of what you are addressing at this point. But I think the Committee is free to think about and discuss and evaluate whether or not something might be recommended by the Committee on the regard of what they think about the intruder scenario --

MR. ESH: That's fine. And the Committee --

MEMBER RYAN: -- the way it evolves.

MR. ESH: Yes. The Committee can certainly recommend that. The intruder assessment is supported by a variety of groups that I have listed here. It's not NRC staff coming up with this idea and methodology. It is used throughout the waste management world, community, as part of their assessments. Not universality -- or not universally, but it is much more common to see it than not see it.

We do evaluate the potential exposure of the intruders after the institutional control period, which is 100 years. A dose limit of 500 millirem TEDE is applied. This is different than the 25 millirem that is applied under 61.41. It is implying an unlikely -- the unlikelihood of the occurrence. You could interpret it that way. And that it is only going to impact a few individuals.

So it's not applying the same dose limit as 61.41. If you thought that this was a probability one scenarios, you would have no reason to not set it at 25 rather than 500. But it is an unlikely scenario that has this implied probability reflected in the dose limit that is assigned to it.

MEMBER STETKAR: But, Dave, now you are starting to talk about risk assessment. That dose limit is miraculously 20 times higher than the 25 millirem.

MR. ESH: Yes.

MEMBER STETKAR: Where did the factor of 20 come from? Is that a surrogate for a five percent probability somehow?

MR. ESH: Well, you can interpret it that way, as a five percent probability, but --

MEMBER STETKAR: Do you know the history of it?

MR. ESH: The history of it is, at the time, Part 20 had 500 millirem as a public dose limit, and they assigned the same dose limit that was in Part 20 at the time. And the reason -- in the current rulemaking, we are -- we want to stick with the 500, because that is what all the table values were derived for.

So we could -- we are kind of in this -- we are kind of in this box of, well, you should assign it to what Part 20 is, which is 100 today, but then it would be inconsistent with the 500 values that are implied by the table value. So we recommend you to stick with the 500, but that's where it came from.

It works out to -- I mean, I think it's self-consistent. It's not inconsistent.

MEMBER RYAN: It is internally consistent within 61, but it is inconsistent with other parts.

MR. ESH: Possibly, yes.

MEMBER RYAN: And other environmental regulation parts as well.

MR. ESH: The last point here on this slide, we are recommending reasonably foreseeable land use scenarios impacted by the timeframe and the change in the natural site condition. So maybe your site is very arid today, and you want to dispose of long-lived waste. Over that long period of time, we know some things about climate cycling. There are a lot of climate scientists out there. They argue with each other a lot.

But the actual fact that climate changes on a somewhat repeatable pattern has occurred in the past, if your site is going to change significantly as that climate change goes on, I mean, I read a report before that they were saying that some of the real arid parts of Arizona were a lot more like Montana at some points in the past.

So, to me, that seems reasonable. If you want to dispose of long-lived waste, you need to think about how your climate and environment are going to change over time.

So that's in general, though, the intruder assessment. It's a very debatable topic, as we have already had.

So one problem that we had from our interactions with our stakeholders is our draft language where in the first bullet here, under number one, we had in the definition, "Assumes that an inadvertent intruder occupies the site."

We think that you don't necessarily have to assume they occupy the site. "Accesses" is probably a better word, and you do -- like I said, you consider the actions of the intruder based on the current land use and the environmental conditions, et cetera.

As you go out over longer periods of time, that becomes more uncertainty, and maybe you do have to be more conservative in your scenarios that you select. But that was a point of discussion in the --

MEMBER BLEY: Well, I'm a little -- my interpretation of "occupies" in there is that whatever he happens to stir up he lives in day in and day out, not just he wandered into it and wandered out again. So it's not conservative to say "access." That's --

MR. ESH: No, it's not conservative to say "access." I think we're saying we should -- it is all right to be less conservative, especially over the few hundred year timeframe, which would make a big difference for blended waste and short-lived waste. It's not going to make a difference at all for longer-lived waste, but we are arguing that you -- it is okay to consider some of these things over the shorter timeframes.

So this language that we'll discuss in the working group, but we may change it from the original -- what went out and what you saw.

So now we are on to the easier topic of the period of performance. We have some very strong opinions on this matter. At the 2009 workshops that we had with a diverse set of stakeholders, they of course couldn't agree on a period of performance, but they could all agree that we should put it in the regulation. So that's what we attempted to do.

I think in our meeting with the Subcommittee Mr. Sieber described it well. He said, "This isn't something that is really amenable to technical proof, or something like that, and I think that is a good description. Or technical rigor. It's not amenable to technical rigor. This is a lot more of an outside of the box problem than an inside the box problem.

In 2010, the ACRS recommended to us to not put a period of performance in the regulation, which was in direct conflict with what we heard in our workshops. I'm going to try to explain in this presentation why we did what we did and how we think we were trying to be consistent with the previous direction from the ACRS.

So the period of performance is one of the many important elements in the safety evaluation of low-level waste disposal, not the only one. There are a whole bunch of things that go into the safety of low-level waste disposal -- siting requirements, technical analysis requirements, the performance objectives. The period of performance is one thing that comes into play, and it's a pretty important one, or it can be.

Different approaches are used within the U.S. and internationally for low-level waste. So, in the U.S., it is undefined right now. That's our policy. U.S. policy, NRC policy, on low-level waste performance assessment, there is no period of performance. Agreement States are free to interpret and develop what they see fit.

Internationally, quite different approaches are used to the period of performance for low-level waste. Many of the European countries, for instance, are much more comfortable with long timeframes, and I think that's because they have been around a lot longer.

The U.S. is much more uncomfortable with long timeframes. But if you go out and look and see what people use and what they talk about and why they are using it, in many cases they will go out to peak dose no matter when that happens, and they will do that for industrial metals, too, not just radiological materials. As I said, we have diverse opinions among our stakeholders.

When you're talking about concentrated long-lived waste, I think that's where the period of performance comes into play. It doesn't really come into play for many other types of materials.

The NRC background on this, it's not a new issue. It has been talked about a lot since 1994. There are a whole bunch of ACNW letters on this, and the ACNW communicated some basic principles that we tried to stay faithful to in this rulemaking, which I will show in the next slide, back in 1997. And that was specifically for low-level waste disposal.

We have very little Commission direction on this. We have an SRM in 1996 that they said provided basis for truncating the period of performance at 10,000 years. That's all the communication that we have from the Commission on this topic.

During this time -- this timeframe, couple of decade or 15-year timeframe, we had a performance assessment working group that was formed at NRC, and they were looking at this issue and discussed it with the ACNW a lot and went back and forth.

Originally, it was a Branch Technical Position, and then they basically couldn't get through with this period of performance issue at that time, and the report was issued as a NUREG, and the staff recommended 10,000 years at that time with longer term impacts in the site environmental assessment.

I think it's important to understand the context of this recommendation. Okay? At that time, they were discussing the performance standards for Yucca Mountain, and Part 60 had a period of performance of 10,000 years in it.

Part 63 initially also had a 10,000-year period of performance in it. And the performance assessment working group wanted to stay consistent with what was being done in the high-level waste program.

Well, eventually, as probably all of you are aware, with the National Academy of Sciences getting involved and the lawsuits and EPA, that Part 63 got revised and they ended up with a million-year period of performance or compliance period. It has two phases to it. It has a 10,000-year initial phase and then a higher dose limit for the second phase, but it is a million-year time of compliance, is

I think how they describe it.

Not all Agreement States have requirements to do the second part of what was recommended by the performance assessment working group here -- the longer term impacts and the site environmental assessment. So part of what we came up with -- the 61.13(e) requirements -- are because of this issue, that the facilities are licensed in Agreement States, and they have different requirements to how they handle -- how they may or may not have to do site environmental assessments.

And the one thing that I will point out as we get to a complicated table in the back is this performance assessment working group recommendation was based on, in large part, a consideration of radionuclide travel times. They looked at one type of condition for that analysis -- a humid, shallow site.

Our recommendation is based on looking more broadly at the types of facilities you could have throughout the U.S.

VICE CHAIRMAN ARMIJO: But you could start off with a very dry site, and for these long periods of time you can't guarantee that a dry site won't become a dry -- a lake. So how do you deal with that?

MR. ESH: Well, the performance assessment has to include the variation in the site environmental conditions over time, which does mean that an arid site could in fact become a more humid site over time. Generally, you switch between, let's say, one box on like a climate classification chart and not multiple boxes. So you don't go from very arid to humid. You will go from semi-humid to humid, or you will go from semi -- or arid to semi-arid type of changes. But they aren't necessarily --

MEMBER RYAN: You can go the other way, too. You can --

MR. ESH: And then you go back the other way.

MEMBER RYAN: Yes.

MR. ESH: And then, absolutely, you go back the other way, yes. But it isn't a change across multiple boxes. But the evaluation has to include the changes in those environmental conditions over the assessment.

Let's see here. The ACNW principles that were expressed -- and, obviously, you are not bound by the past ramblings of your elder Committee members, but --

(Laughter.)

-- but we considered them, because that's what we had, and there is a lot of good information in there. One of the messages that they had was that we should consider the site-specific characteristics, and they said, "Okay. No less than the time for the more mobile radionuclides to produce a peak dose."

Well, that's great. What does that mean? You know, there is a big difference between this -- converting this principle to practice. And I think when you convert it to practice, it becomes a bit of a challenge, and I will talk about that on a slide coming up.

MEMBER RYAN: David, there is one element of context here that I think is fairly important to grasp. During this time period from -- and this is the late '70s. By the way, this is before my time on the ACNW.

(Laughter.)

By a lot.

(Laughter.)

Waste form, waste packaging, and waste processing has changed dramatically since -- you know, look at every decade, the '70s, the '80s, and the '90s, with step increases in the quality of the capability of the waste form and the waste package to retain radioactive material.

I mean, the burial method in the 1970s was affectionately known as the "kick and roll method" of waste disposal. And, you know, cardboard boxes were disposal containers, and so on.

So I think that you have to keep in your mind that as you march forward every decade there is a whole lot of difference in what is disposed and what the first two barriers are -- the waste form and the waste packaging -- and what maybe the predecessors on the Committee had in their minds when they were thinking about all of this. Is that a fair comment?

MR. ESH: I think it's fair. The issue becomes how much, even now, you can rely on the engineering as you go out over extended periods of time.

MEMBER RYAN: I'm not talking about an extended period of time. I think we've beat that one already. Let's move on off of that one for now. But if you want to think about the disposal system, you know, there are really some significant changes in what that has looked like over time, and you have to make sure that when you're talking about what happened in the mid-1990s you are talking about what was, you know, then a very much evolving and improving waste form and waste packaging setting.

MEMBER BLEY: I haven't read their letter, rightly, but I also suspect they weren't talking about DU. But you haven't come to my other question yet, so I'll wait for that.

MEMBER POWERS: Well, the question I would ask, Mike, is you are absolutely correct the way the packaging for disposal has changed dramatically. And the question is: why? Why have we gone from literally throwing it in a cardboard box and dropping it into a trench made with a backhoe in the back 40 to more sophisticated systems?

MEMBER RYAN: There is a couple of reasons, in my opinion, and I would ask the others to offer their views. One is, as the disposal costs have increased, and the disposal currency is volume, efforts went into putting as much radioactive material into a given volume as possible.

So processing water with resin, further reducing resin volumes, using robust containers so you can stuff more into it, and all those kinds of things I think were part of the thinking.

The other is I think utilities and other generators of waste decide that accumulating waste on their sites really wasn't part of their business. So getting it processed and getting it disposed efficiently, quickly, and minimizing their inventories of onsite wastes, was also going on at the time. I think those are two of the key drivers -- all, again, intermixed with the fact that pricing went from $3.50 a cubic foot to probably $350 a cubic foot. So that's really the essence of the change.

MEMBER POWERS: All those things. And the question I would tend to ask is, we could forecast some continued development in that, and presumably every step there makes the material less likely to be dispersed into the environment. I make that assumption. I don't know that it's true, but it seems to me like it's true.

MEMBER RYAN: I think that's a general trend for sure.

MEMBER POWERS: Is there a point where we reach adequacy and one shouldn't do this better engineering and what-not? Or is it always going to occur?

VICE CHAIRMAN ARMIJO: That is a problem with the time. You can have a material that you can prove without any question that it will last 100 years, maybe 1,000 years, maybe 4,000 years. You get out to 20,000 years, or 100,000 years, all bets are off, because the environment is changing, there is an oxidation phenomena, there is a whole bunch of things that can happen.

So if you keep the timeframe reasonable, then I think you can reach a point where you can demonstrate it and prove it, even to a critical reviewer.

MEMBER RYAN: At some point, the criteria, you know, for the performance of the site is where you begin to ask or answer the question, Dana, that it's time to stop. We know with some margin of uncertainty being accounted for or some variability of the result being taken into account that you can say, "This is going to perform to the standard, we think, with a reasonable confidence," so that we can say, "That's enough." I think that's certainly doable.

But at the point you make that decision, it's not just, how much does it cost and what is the next cigar box we can put stuff in? It's, well, are we meeting the objective, and is there a margin of certainty that we are meeting the objective, which is one of the questions you put forth earlier, Dave.

MR. ESH: I think whenever the regulation was developed, and then through our performance assessment working group and in our high-level waste program, they all -- the staff all felt -- and I agree with them -- that we can make credible scientific extrapolations over a 10,000-year timeframe.

We also felt that there isn't significantly more uncertainty associated with going to 20,000 than there is with 10-. There would be if we went to 100,000 or a million, but there is not a big difference in uncertainty space when you're talking 10- or 20,000.

And based on the technical characteristics of this problem, when we look at near-surface stability, the characteristics of this specific waste stream that the Commission gave us direction to try to include in the framework, and radionuclide transport, it all said we should step out a little bit longer to account for those three things. And I will talk about them in detail.

MEMBER RYAN: What the Commission wanted you to include, are you talking about DU?

MR. ESH: Yes.

MEMBER RYAN: Uranium?

MR. ESH: Large quantities of depleted uranium.

MEMBER RYAN: I hate to beg to differ, but 10- to 20,000 years isn't even a blink of the eye in the decay of uranium.

MR. ESH: No. But I will talk -- I will talk about the waste characteristics in a slide here, so let me get back --

MEMBER RYAN: Okay. All right.

MR. ESH: -- to it.

MEMBER RYAN: But, I mean, that kind of needs some detailed --

MR. ESH: I'll explain it to you.

MEMBER RYAN: Okay.

MR. ESH: I think we talked about it at the Subcommittee, but --

MEMBER RYAN: I just want to kind of --

MR. ESH: The second tier from the ACNW principles was to evaluate the robustness of the facility over the range of external processes and events, and then also look at and ensure that no significant changes in the dose from disposal site will occur.

Well, that's fine to say, but what does that mean? What is significant? If I have a dose of 25 millirem for the first 10,000 years, and then I get a million millirem at year 50,000, is that significant? Does that fail, or does that pass, you know?

Right now, the approach we are taking is we are not specifying a dose limit for those later times. We think the stakeholders deserve transparency of information. And if NRC was regulating the facility, we would consider those longer-term impacts in the site environmental analysis.

We think that is the proper context to put something like that, because you are not locked into a radiological licensing box. You are able to look more generally at what the impacts are, are there net benefits to the activity, those sorts of things, what is transportation risk, all of the other components that go into the evaluation.

You can put it in a better context, so the staff -- I will talk about that in our recommendations, but we feel we were consistent with both of the sets of principles expressed by the ACNW in some of their past discussions.

The ACNW also talked about things like near-surface stability and -- what was the other one I wanted to make sure I remembered to say? Oh, the source term hazard characteristics. So one thing they said is if you don't see the activity arriving at your receptor location in this period of performance that you select, then maybe you need to consider the source characteristics of the hazard in defining that period of performance.

Well, in the case of uranium, that's going to put you out at two million years or so if you are considering the source characteristics of the hazard. Is that what they intended, or not?

The last guidance that we got from the ACNW on this topic prior to your March 18th -- prior to the ACRS's March 18, 2010, letter was to maybe consider the previous Committee evaluation to go with a peak dose approach, because they said the peak dose approach is going to consider all of these variable conditions that determine when your peak dose occurs.

Whether it's different waste in a particular facility, or whether it's the different characteristics of different facilities, that will be reflected in when the dose may arrive at a point in time in the future. But I think the problem you run into is for a material like depleted uranium, or other long-lived isotopes that travel slowly in the environment, is that really what was intended? I don't think it was what was intended, and we interpreted it differently. But maybe I'm wrong.

So the general objectives that we used or considered when we went through this period of performance selection process is we wanted to provide protection to the present and future generations. The difficulty is how you set that protection for the future generations.

We also wanted to consider uncertainties. We wanted to ensure that we communicate what the long-term impacts are, and we wanted to facilitate decisionmaking. This is something we were talking about earlier. Is this going to facilitate decisionmaking or not?

So what does the selection process look like? Well, we did a literature review and tried to determine what people consider, and they will generally consider the characteristics of the waste, what is the analysis frameworks, or what's the regulatory framework that you are applying.

They will look at uncertainties. Especially in performance assessment, we tend to look at natural and engineering-associated uncertainties. We do not look at technology-related uncertainties, because the policy is it's -- they're intractable to project over long periods of time, or even moderate periods of time.

And we try to limit the speculation on the societal uncertainty, so we do that with reasonably conservative scenarios to apply to the dose assessment. So I think, Dennis, this was a question you asked about, what are the scenarios associated with the different things.

The intruder assessment is generally done looking at whether the waste is distinguishable from the natural media in that location, first of all. If it is, then you're looking at a discovery scenario where somebody starts putting in a house, they put it in at the disposal facility, they dig up material, and they say, "Oh, we put the house in in a bad spot. There's barrels of stuff here. We need to stop."

So the dose assessment looks at a short period of time of direct radiation exposure, maybe some inadvertent dust inhalation, pathways like that associated with a discovery scenario, what happens in that evaluation.

If the material is indistinguishable from the natural material, then you have an acute scenario where somebody builds a house, if the material was disposed of shallowly -- and shallowly, we are talking the upper three meters of the land surface -- so they can potentially put a house foundation into the waste.

The acute construction scenario, somebody builds the house, takes 500 hours or so to build the house, I believe it is, and they are exposed to direct radiation and dust exposure and those sorts of things, but they are not drinking water or growing plants or living there. They are just guys building a house, basically.

If the material is disposed of more deeply than that, then they look at a drilling scenario where somebody tries to put in a water well, maybe a natural gas well or some other type of well that they punch a hole through it, some of the waste comes up with the cuttings, and then they analyze the exposure pathways associated with that scenario.

Only in the event that the material is disposed of shallowly, and it's indistinguishable from the natural materials, then do they analyze the chronic scenario of somebody could live in the house, and they have a garden. There's two types of scenarios, generally, a resident -- a resident scenario and a resident farmer.

The resident farmer is they have all the pathways. They have cows and chickens and meat and grow plants, and the plants are contaminated, and the animals eat the contaminated plants, and so on and so forth.

The resident scenario is just somebody living in a house. They have a garden. You know, they sleep there, they have offsite time that they are not exposed, onsite time that they are exposed, that sort of scenario.

I don't know if that answered your question or not.

MEMBER BLEY: And you can get me to a half a rem with DU without killing me from heavy metal poisoning first?

MR. ESH: I don't know the answer to that. That's a good question. You can get to a half rem with DU with large quantities of concentrated material. That -- with large quantities of depleted uranium, you have to keep it covered, you have to keep it protected, from a radon perspective.

And all you have to do is think about the radon in your house and what are the concentrations of uranium that are driving the radon concentrations in your house, just to understand, if you have concentrated uranium, and large amounts of it, how it can translate into a problem, especially from a radon perspective.

MEMBER RYAN: David, isn't there an equilibrium question there? I mean, if you have DU, it's going to be way, way, way down the road before you even have to think about radon.

MR. ESH: There's an in-growth equilibrium question that comes into play, yes. It has to --

MEMBER RYAN: Depleted uranium materials -- it's going to be --

MR. ESH: It has to --

MEMBER RYAN: -- way longer than any period of time we have talked about today.

MR. ESH: It has to come in over time, but I will talk about that on the waste characteristics slide. Remind me to go back to it.

MEMBER BLEY: Have you guys done any calculations to support this?

MR. ESH: We have done a variety of calculations to look at the impacts, yes. In the SECY paper in 2008 for 08-0147, we did a technical analysis to look at, well, do we need to do this rulemaking? What's the issue here? And if you dispose of the material shallowly, or you dispose of it at a humid site, those are the two most direct pathways to cause a problem. You can --

MEMBER BLEY: I'm sure I looked at that SECY paper. Do we have -- I want to see that, so -- we'll get that.

MR. ESH: Yes. Yes. Feel free to look at it.

MEMBER BLEY: Is that the best source you've got?

MR. ESH: That's the best source we've got, yes.

MEMBER BLEY: Okay. I'll take a look.

MR. ESH: And what we tried to do there is we didn't present the material in dose outputs. We presented it in percentiles of various configurations that would exceed the limits, because we were trying to do an analysis that represented a whole range of site conditions that could apply over the whole country and disposal depths.

So it doesn't make sense to average that. You know, we have this issue of what -- if you're doing an analysis at a particular site, you have intra-site variability, but not inter-site variability. And that analysis had to look at both intra- and inter-site variability. So --

MEMBER BLEY: And I take it since you only regulate the radiotoxicity you didn't look at whether the chemical toxicity would have beat you to the punch.

MR. ESH: We did not, and we also didn't look at things like, at what point does a soil-to-plant transfer factor no longer apply? So when you get the X percent uranium, or X parts per million uranium, maybe plants don't live anymore.

I did work with a colleague that -- he had experience on a project where the uranium concentrations were much lower than what we are talking about here, and he said, "The trees actually turned yellow from taking the uranium up into trees."

MEMBER BLEY: The heavy metal aspect of it.

MR. ESH: Yes, yes.

MEMBER BLEY: That's what I suspect is --

MR. ESH: Commenters asked us about that, though. They said --

MEMBER BLEY: I'm sorry. Who? Oh, commenters.

MR. ESH: Commenters asked us about that on the comments on the rulemaking package as -- what about the chemical toxicity, not just the radiological toxicity?

MEMBER RYAN: Well, I mean, correct me if I'm wrong, but my understanding is it's more of a chemical toxin than it is a radio toxin, from a human exposure perspective.

MR. ESH: Early on, but as the material ages and Mother Nature puts the daughter products back, it does not -- this is not a trivial material to deal with.

MEMBER RYAN: No, no, I agree with you.

MR. ESH: I'm not going to try to assert -- because I haven't done the calculations -- how the chemical risk compares to the radiological risk. The chemical risk is EPA's business. I'm just telling you that the radiological -- huh?

MEMBER RYAN: It's also OSHA's business.

MR. ESH: Yes. The radiological risk is what we are managing, and the radiological risk can become significant.

MEMBER SIEBER: And it gets worse with time.

MR. ESH: Yes.

MEMBER RYAN: Long time. If you have pure uranium materials, I guess I would ask that we address that question in detail is -- what is the period before I get to an equilibrium with radium-226 before radon becomes an issue?

MR. ESH: I'd say, Dr. Ryan, you can look at the appendix to the technical basis document --

MEMBER RYAN: Okay.

MR. ESH: -- where we did a couple of calculations of just soil resuspension and inhalation of that, and then a simple calculation of radon at I think it was 10,000 years, or maybe it was 1,000. And you can look at those numbers. Both of those numbers are -- maybe I'm not remembering. Both of those numbers were over 500 pretty easily, over 500 millirem. You are talking --

MEMBER RYAN: Okay.

MR. ESH: You are talking like 5,000 millirem. It's because it is concentrated uranium. If it's concentrated any metal, it's going to be hard to deal with. I don't care whether it's uranium, lead, mercury, zinc.

MEMBER RYAN: But the devil is in the details. You assume all the radon produced readily escapes from the matrix of the material without decay?

MR. ESH: No. You apply an emanation factor, like you normally do for any material. And emanation factors are all over the map from .02 to .7, depending on the material and the natural conditions. So this isn't a I guess make it a problem problem, it's a what's the material we are dealing with, let's assess it problem. So --

MEMBER RYAN: All I'm suggesting is that the devil of -- you know, or the importance of some of these things is in the details of what the assumptions are and the calculations supporting it. I mean, that's an obvious thing to say, but, you know, sometimes, you know, reasonable people can disagree about what reasonable assumptions are to make these calculations.

MR. ESH: Yes. I would say it's easy -- you can look at -- think of the problem this way. The uranium -- natural uranium ore bodies in the U.S. are a few tenths of a weight-percent uranium. Okay? And in a few places, like Canada, they have some that are very high, 40 weight-percent or more uranium.

They have to do robotic mining at those locations because of the radiation levels. And if you put a lot of depleted -- concentrated depleted uranium in one facility, it's a hard problem to deal with. That's not an easy problem.

It doesn't matter what you do with the -- you could do the analysis very conservative and make it an extreme problem. But you can do a credible analysis and even a non-conservative analysis, and it is still a challenge that you need to deal with.

Whenever we looked at the selection process, something that we talk about in the paper -- I'm not going to cover today -- is the transgenerational equity and discounting and all of that that comes into play. It's kind of softer to engineers, but it's important for this problem.

We didn't attempt to do -- you could do a socioeconomic evaluation to set a period of performance, and you could use that to argue what you would set it at for any material, that that's what you should do for society. That's a much more complicated problem, and we didn't attempt to do that here.

VICE CHAIRMAN ARMIJO: It's very subjective, too..

MR. ESH: And it's also very subjective, you're right.

VICE CHAIRMAN ARMIJO: But, you know, the fundamental problem I have with this is that future generations -- your basic assumption is that future generations and their governments, the people and their governments, are unable to protect themselves. They have lost memory of what is out there. They don't seem to -- they don't -- they are basically incapable of protecting themselves, and I don't share that.

MR. ESH: I don't think it's a matter of that they're incapable of protecting themselves. But the way these processes work is the radioactivity exits the facility nominally, usually, in 61.41, through the groundwater pathway, ends up in an aquifer, and eventually ends up in a water supply of some sort, whether it's a stream, a well, a public water supply, whatever the type of water supply it is.

You don't know that the radioactivity gets into your water supply until you find it in your water supply.

Now, you could argue that people are going to be testing and analyzing their water supplies, and they do it now, and they analyze it for radioactivity, and they would have a gross alpha or gross beta measurement of some sort, and they'd say, "Hey, we're starting to get radioactivity in our water supply that is above what we intended."

But over these timeframes, I think you have to have continuity of -- you have to have continuity of this understanding that relies on things like records and things that aren't durable. I would say, has any of you ever held a 500 year-old record? I doubt any of you have ever held a 500 year-old record.

VICE CHAIRMAN ARMIJO: Yes, I've had books.

MR. ESH: Well, okay.

MEMBER BLEY: Through a glass.

(Laughter.)

VICE CHAIRMAN ARMIJO: Go to Salamanca University and you will get 1,000 year-old books.

MR. ESH: The point is that it's much more unlikely than likely that you have done that.

VICE CHAIRMAN ARMIJO: You make an assumption and you assert that society will basically become less confident in the future than they are today, and, therefore, you have a current obligation to generations in the future, assuming that they can't protect themselves at all. And I don't share that.

MEMBER BLEY: And I'm not sure if I'd go as far as Sam, but I'm -- you just mentioned that -- and I'm not saying go do a socioeconomic analysis, but you said, "Wow, that's a big analysis. That's hard."

The impact of this proposed change I think will direct that kind of effort and what this is going to require for people to do to respond to it. So, you know, analysis is cheap by comparison I think to --

MR. ESH: But in what way, because the period of performance is undefined right now, and our Agreement States have used anything from 500 to peak to 50,000. So I don't understand what the big -- the big opposition to this is when they do it that way right now.

And in the field of performance assessment -- this isn't an NRC issue. Performance assessment uses these long periods of time and this type of analysis internationally. So if you want to make the comment of "It's the wrong way to do it," you are free to do that. That's what -- we don't have the ability to change the international framework of how performance assessment is done.

VICE CHAIRMAN ARMIJO: I'm not saying we need to attempt what the international folks do. We have to do what's reasonable and practical for the United States. And if this is just a depleted uranium problem, then there may be a better way to treat it.

That's why I got to my earlier question, is there some preferred form, waste form, in which a lot of the engineering uncertainties -- radon emanation, stuff like that, would be more tractable than as powders or filings and stuff like that, and you can push towards a favorable form, so that it makes the engineering problem much more -- you could deal with it.

MR. ESH: Yes. And what I will try to show you here is that the rulemaking was initiated in part because of the depleted uranium issue. But I would argue that the issue is more generic than that.

VICE CHAIRMAN ARMIJO: Well, okay.

MEMBER RYAN: Let me -- it will just take me 20 seconds to advise the members. We have about a half hour to go on this Subcommittee. We do have some more time scheduled for it down the line. I'm going to ask that we maybe let David get through this slides, and if you have questions that you mark them as we go along. And maybe we can handle some of them today, maybe we'll take them up after we consider them in more detail between now and our next meeting. Fair enough?

VICE CHAIRMAN ARMIJO: Sure.

MEMBER RYAN: Thank you.

MR. ESH: So waste characteristics here is one thing that people generally consider, and even the ACNW mentioned for us to consider, and we did, and we looked at, okay, what is the activity of low-level waste compared to something like a depleted uranium waste stream?

And I generated this figure on the left, which I -- now, if there's one regret I have in this process, I wouldn't have, because I think it has caused a lot of misunderstanding.

The performance assessment is, of course, about ensuring that you contain the short-lived material. But ultimately the performance assessment is about not this 99 percent that decays in place, but it is about the one percent that remains and whether it can cause an undue risk to somebody.

So the performance assessment is about what is happening for this fraction that ends up out at some longer time. You can argue about what that longer time should be. It's not about the material that is short-lived. The short-lived is easily managed with the engineered features and controls that people use today.

The issue of -- this issue is an aggregation issue, I think, so the material that is presented here is on a radionuclide basis. But when you aggregate the issue on a facility basis, what I'll show in a few slides here is that all our current facilities have long-lived waste in them. And they have what I would say are fairly significant amounts of long-lived waste.

So it's -- you can put depleted uranium in it, which is another couple orders of magnitude challenge in the problem, but the issue is not going to go away. It applies to all of the existing facilities that we have.

So this argument that maybe we should only consider 1,000 years, because most of the waste decays, I would say that same argument applies to high-level waste. Most of the high-level waste, or a small percentage of it, remains at 1,000 years, just like it does for the commercial low-level waste.

There is no reason to -- if you're just looking at decay curves, to interpret those differently. In either case, the performance assessment is looking at what remains at some point in time.

So on this figure on Slide 15, it's from NUREG-1538, which the high-level waste program developed. And they considered, well, what is the -- when does the material approximate that of a natural ore body? That would be a good thing to know, because that would say, okay, once it approximates a natural ore body, why should I protect that any more than I would worry about a natural ore body? I think that makes a lot of sense if you're trying to regulate what -- the safety over time.

In this case, they looked at -- and it was a site-specific analysis for Yucca Mountain. They looked at when it approximated a natural ore body. It was factoring in things like solubility limits and how things reduce the dose or reduce the concentrations it may get out of the facility.

But they came up with 10,000 as a pretty good number for when disposal of high-level waste, in a geologic repository, would approximate the risk from that of a natural ore body. And I think that was a good line of argument.

The problem is, for near-surface disposal, it is completely different stability issues than for geologic disposal. The other argument associated with the geologic disposal is that if you have geologic stability for 10,000 years, you are likely to have it for much longer. That isn't the case for near-surface disposal. Climate effects come in. Your near-surface stability issues get worse over time. Just because you might be able to demonstrate stability for 1,000 years doesn't mean your site is going to be stable for 10,000 years.

But the bottom line is that the period of performance that had been selected in NRC policy space, it's not a pure policy decision, such as, what's the risk that -- what's the obligation I have to a future generation over time? When do I have to consider that future societies can mitigate their own risks?

That's not what has been done -- NRC

policy. NRC policy is to consider these -- some of these technical issues and use that to help formulate the period of performance that is selected for a particular problem. And that's what we did here.

So I also want to show you this analysis that we did to give you some more context. We looked at the actual inventories disposed at four different low-level waste disposal facilities using the DOE MIMS database. That database you can get information on what has been disposed of at a particular facility by isotope in a particular year. It does have some limitations. Generally, it starts in the '80s for each facility, and in some cases we know that some significant disposals occurred prior to the time that the database starts.

And also, some of the information may be complete -- incomplete, because we got information on Agreement -- from Agreement State regulators on actual uranium disposals. And the database was generally lower than what we got from the Agreement State regulators.

But what I'm going to show you here is we calculated the reduction factor that you need from the waste to the groundwater to meet the 25 millirem, to show you on an isotopic basis, what are you dealing with in low-level waste.

The performance assessment process is how you go about to verify that you are going to get those reductions. So you look at things like sorption and solubility and dispersion and dilution. That's the whole performance assessment process.

The next two slides are not performance assessment results. They are just trying to give an apple-to-apple comparison for material.

So if we look at this figure on Slide 17, this is a plot of the reduction factor versus the half-life of the materials. What you see is that at the -- in a given row here, it gives all of the isotopes for the four different facilities by symbol by half-life. So this row is strontium-90. That's the amount of strontium-90 that has been disposed of at four different facilities.

Next is americium-241. I only included a couple of short-lived isotopes on here. It wasn't necessary to put them all on here, because they -- it has the same general behavior. But I did put a lot of the long-lived ones for which inventory is reported, including uranium-238 and thorium-232.

And what you see from this figure -- and I would argue -- is that you have increasing challenge

-- and I think the Committee has expressed this -- as you need bigger reductions, and you have longer-lived material. Longer-lived material and bigger reductions is a much harder technical problem. It is going to require you have more knowledge about your site and more basis for what is going to happen.

The Commission direction to include blended low-level waste or large quantities of depleted uranium, add these red symbols up at the top. It's an increase in the concentration of material that you are dealing with in each case, whether it's long-lived waste or whether it's short-lived waste.

The other point I would like to make is that here is a group of symbols associated with uranium-238 and thorium-232. That is already disposed of in the facilities. All of these four facilities have a decent amount, or large amount depending on your perspective, of long-lived waste.

The Commission direction to add large quantities of depleted uranium takes that out further. But the issue of long-lived waste is still present in low-level waste disposal.

Now, this isn't quite the full picture, and I also should caveat it that this is just the parent nuclide and the water pathway. What you'd really want to know is all the pathways and the decay change, what comes in in the daughter.

So when you're looking at uranium-238, you're -- not all the daughters. You talked about, well, what is the -- it's pure uranium. This is just the pure uranium impact. It's not the lead-210 and the radon and everything else that comes in down the line.

So you need a significant reduction out of your facility to get to your performance objective in, say, ground water for some of these isotopes.

Now, that -- you say, well, that's fine and good, but you can't get from waste to water directly like that. There's things that go on.

So this next slide on -- figure on Slide 18 is we said, "Well, let's factor in geochemistry, and we will use a geometric mean distribution coefficient for these different elements as a proxy for how much geochemistry is going to reduce the risk of these elements."

And what we have shown here is that for something like the thorium it drops down much more significantly than the uranium, because the thorium is more insoluble, less mobile in the environment, compared to the uranium, which is kind of moderately soluble, moderately mobile; unless you are in reducing conditions, then uranian can become very immobile.

So, you know, if you want to talk about technical things that you could do to mitigate uranium, well, the best thing you could do is put it in a reducing environment, which would probably not be a near-surface environment. There are many other reducing environments that you would consider.

MEMBER RYAN: Put in reducing agents.

MR. ESH: Or put in reducing agents, enough reducing agents that you had confidence of maintaining those reducing conditions. Very good point, Dr. Ryan.

So the point being that the technical requirements in the rule have to allow you to distinguish when you have a significant quantity and when you may need an inventory limit, and when you might not need an inventory limit.

And what I would argue is that the intruder analysis, especially with the shorter-lived waste, assuming that it's an intruder analysis that allows you to take into some consideration some things that would mitigate that risk, like land use and proper scenarios and those sorts of things, it is important for the blended waste especially, but any concentrated short-lived waste, it doesn't have to be blended waste, that's just the thing that came up at this time to put it into our rulemaking.

Likewise, the long-lived waste, the period of performance affects how you would determine whether you've taken too much or whether you've taken an appropriate amount of that material.

The period of performance, if you set it very short, just by the basis of the transport through your aquifer system, it could be arriving after your compliance period, and it could cause a very large impact. You get delays in your system from the site characteristics or the engineering. You want those things, but you also want to understand what your risks are, especially as you go out in time.

And so the period of performance and the intruder analysis were the two parts of the regulation that we felt that deal with these different types of more concentrated materials. It doesn't matter when it's called blended waste or depleted uranium. If it's long-lived concentrated material, or if it's short-lived concentrated material, these are the two areas of the regulation that we felt were -- needed the requirements to mitigate those risks.

This is a conceptual figure. I won't

spend a lot on time on it. It's just trying to convey uncertainties. I think the Committee has talked about this issue of technology, and to me I agree with you that technology is a big factor in what the risk -- the actual may be over time.

I just don't see how you credit it in the regulatory analysis, because many stakeholders out there, a lot of academics and other regulatory communities, they don't credit something like that, and they say it's because you can't project those things accurately over the assessment period.

MEMBER RYAN: Just one comment on that point, David. I think -- and, again, I have said it many times, but, you know, you are part of a very talented performance assessment crew that has insights in all of this. And whether it's probably not in the regulations the best place, but I can see the need for NUREG guidance and other kinds of technical analysis guidance documents that will take a licensee through some of what the details of this are, because as I think we would all agree, the devil in this is in the details and what you do and how you calculate it and all the rest. So --

MR. ESH: Yes.

MEMBER RYAN: -- somewhere this, you know, knowledge that you and the team have amassed needs to be put forth, so that everybody can use it, and, quite frankly, everybody is on the same page with what the expectations are.

MR. ESH: Yes. And I think we've done that. We have a guidance document that we are developing in parallel with this, and it has quite a bit of detail on all of these topics that hopefully we can talk about at the Subcommittee meeting in August.

MEMBER RYAN: Sure.

MR. ESH: It's coming along. It's getting close to a concurrence process document.

MEMBER RYAN: I just want to preview for the other members that, you know, licensees won't be in isolation trying to figure this out on their own.

MR. ESH: We recognize that these are not easy problems and easy issues, and we felt very strongly that we needed some guidance to go along with this. And the rule text is not going to be issued in a vacuum without that guidance.

Guidance is a key part of it. It's just a bigger effort, not by number of people but by content of information, and it -- we didn't have it ready to talk about at the same time as the rule text, so --

MEMBER RYAN: Okay.

MEMBER BLEY: Can I just ask one question, because I lost the context. Early in the session Mr. Camper said something about you were directed to risk-inform some aspect of this problem. I don't remember what it was, and I don't remember it from the SRM.

MR. CAMPER: What it was, when we did SECY-08-0147, which is the SECY that is associated with the depleted uranium question --

MEMBER BLEY: Okay.

MR. CAMPER: By the way, we did a technical analysis.

MEMBER BLEY: Okay.

MR. CAMPER: When the Commission came back in the SRM associated with that paper, it told us to do two things. It said proceed to do a limited rulemaking to require site-specific performance assessment for large quantities of depleted uranium. It also said to do another assignment, and that is to budget to risk-inform the waste classification scheme in 61.55.

MEMBER BLEY: Okay.

MR. CAMPER: We assumed "to budget" meant to do, and that's how we are proceeding, with the emphasis in FY13.

MEMBER BLEY: Okay.

MR. CAMPER: But they also emphasized when you do the risk-informing of the waste classification scheme, take a close look at this thing called depleted uranium when you risk-inform. That's the assignment of --

MEMBER BLEY: Okay. Thanks for the context.

MR. ESH: So on this uncertainty slide, I am trying to convey a lot of different things. When you go out to these very long times, you have to start worrying about things -- extreme natural events. And one argument that we hear is that, well, the uncertainty is so large that we need to -- the numbers are meaningless.

And I would say, well, you have to think about that as what -- why should you take the action if you don't know the impacts of the action? You should have some confidence that you're mitigating the impacts, and that they aren't significant. And the process and the regulatory requirements should allow you to get between those -- between Points A and B to do that.

We do want to understand -- acknowledge, though, that this waste disposal problem is in a much bigger context of what is going to be happening with people, the world, and everything else. And those uncertainties very well could be more significant.

But as I said, you are talking about a different analysis, a different type of analysis, in order to justify what you would pick out of that outcome, an analysis that we haven't done, and I'm not aware that anybody has done, in any international waste development program.

So it's something that, you know --

VICE CHAIRMAN ARMIJO: Maybe the basic problem is you really shouldn't treat this as a bury-and-forget issue, because the analysis gets to be so complicated and so -- so much uncertainty in it for so long a time that a more practical way is a periodic reassessment.

It is never really buried permanently unless, you know, every 50 years somebody does a reassessment and somebody pays for it and says, "We'll go as we" -- you know, because every step in this analysis, whether it's materials degradation, whether it's flooding, whether it's land movement, whether it's societal issues, it's open ended. And any scenario that you put together, and any number you put out, is readily challenged by any number of people.

MR. ESH: And that is a comment under our options considered here, Option 5, as we consider an option that would be like an industrial metals approach, which is what you just described.

VICE CHAIRMAN ARMIJO: Okay.

MR. ESH: And in the end, we didn't select that option, because that's not the Commission's policy or framework for managing this type of problem. The Commission, whether it's in uranium mill tailings, low-level waste, decommissioning, or high-level waste, they do not take that approach.

MEMBER RYAN: One thing, David, I think is certainly catching my attention in going through this again with you all is this -- a couple of times we've heard about, well, you know, we're following the Commission direction, which is all well and good, but I get the sense that some of these other options that weren't in the Commission direction might have been beneficial to evaluate.

So there is something I think very important for the Committee to understand that, you know, maybe the SRM and the direction to the staff wasn't wide enough.

MR. ESH: Well, I think that the issue that was first presented to the Commission was how you go about managing or classifying this particular material.

And some options were presented to them in the SECY-08-0147 Commission paper, one of which was, well, let's just analyze it the same as the materials that did end up in the regulation were analyzed, because Sandia National Lab developed an optical character recognition program and got the old programs running.

We could just throw uranium into those programs and generate a number for it, and then put a uranium number in the table. So that would be -- that would have been one solution. They opted not to choose that, I think in part because they wanted to recognize that that approach, while sufficient, was not necessarily risk-informed, because you're applying the same analysis and same conditions to all sites, no matter what their conditions and natural variability may be.

So they were presented with options within how to do the waste classification part of the problem, which then led to this rulemaking process and these changes we are attempting to do here, but this bigger issue of what's the overall framework, you are asking questions that are much bigger than the direction that we received for the limited scope rulemaking.

And I hope we would consider it within the broader effort that we do in the future, if it's budgeted for. The Commission has to decide if this is a priority and whether they want to -- want us to do that activity or not.

MEMBER RYAN: I think some of the sticking points, though, are in that latter space, rather than in the -- that's my view of it.

MR. CAMPER: Allow me to make a comment or two on this point, because several times in your Committee you have touched upon this, and let me just give you sort of a pragmatic viewpoint about it.

MEMBER RYAN: Just tell them who you are again.

MR. CAMPER: Larry Camper. I'm sorry. The challenge that we face as a staff, and that the Commission faces, really, is indeed a practical, imminent problem. The disposal of depleted uranium and the disposal of blended waste is before us. It is imminent. The disposal of these two types of products is imminent.

When we started wrestling with these two issues and communicating with the Commission, first, on depleted uranium, and then when we briefed the Commission on blending, and the Commission directed us to add blending to this particular waste -- to this particular rulemaking -- during that same briefing this question of, what about Part 61 at large came up.

And we do have that assignment, as I mentioned earlier, and we have identified another SECY, we have identified five options in that SECY from looking at Part 61 overall. At least one of the Commissioners, in fact two of the Commissioners, were quite concerned about even adding blending to this particular rulemaking, because of the concern that if this rulemaking got bogged down it could have an impact upon the ability for industry to dispose of blended waste.

So what you have in the final analysis, then, is two issues that are imminent at this time, that being the disposal of large quantities of depleted uranium -- and, yes, the Department of Energy has a very large quantity sitting on pads at Paducah and Portsmouth at this point in time, which were being exposed to the environment over time.

And, yes, the question of blending is going to become a reality, it would appear.

MEMBER RYAN: Just so I'm clear, Larry,

the industry waste that you're talking about is Department of Energy uranium-related waste.

MR. CAMPER: That's correct.

MEMBER RYAN: So it's not industry waste. It's not what these folks around this table --

MR. CAMPER: But they do want to dispose of a portion of it in the commercial facilities.

MEMBER RYAN: Fine. But it's DOE uranium waste, not --

MR. CAMPER: Correct.

MEMBER RYAN: -- licensees or the NRC and Agreement State waste.

MR. CAMPER: I'm only pointing out that these two challenges are imminent.

MEMBER RYAN: Okay. That's fine. I just want to make sure we frame exactly what we're talking about.

MR. CAMPER: And then, the question of looking at the Part 61 much bigger, you raise many very good question about Part 61 and its construct. The thing we have to be cautious about, though, is that Part 61 is well known, it's established, it's adequate to protect public health and safety. It's not perfect.

And any movement into -- when we start

moving more closely into recommendations to the Commission about what to do about Part 61, which we owe in December of '12, I think will head into, depending on what the Commission decides to do, of course, a very extensive rulemaking that will take minimally, in my view, at least four years.

And so you have to weigh -- all I'm saying is you have to weigh the challenges that are before us now juxtaposed against what it would mean to look at this regulatory part that has been around for 30-plus years that has worked, overall, rather well. So just a practical observation.

MEMBER RYAN: Thank you.

MR. ESH: So I have eight minutes and eight slides.

MEMBER RYAN: No, you have seven minutes.

MR. ESH: Seven minutes and eight slides.

(Laughter.)

So we considered options. We -- in the paper that you hopefully have and looked at, we had some rating factors that we developed and tried to, at least in a qualitative manner, evaluate these options. What we ended up with is -- our recommendation was for Option 3, a two-tiered approach, which was consistent with past ACNW direction.

We have a compliance period of no less than 20,000 years, with a 25 millirem TEDE limit. This is for 61.41. And then, a requirement to perform a calculation over these long times to provide transparency of information to stakeholders that we wouldn't apply a dose limit to in the regulatory analysis.

If NRC was regulating those facilities, we would take those impacts, whatever they may be, into account in the site environmental analyses which are performed.

And then, we also reflected in the changes -- we wanted to highlight the uncertainties associated with the disposing of long-lived waste and that limitations on disposal of these uncertainties may be needed to properly manage the uncertainties. This was clear to us in Commission direction that was given to us in the SRM on that 08-0147 paper.

And, let's see, our basis for the 20,000 years, it had three elements to it primarily. We looked at the performance objectives, and we wanted to consider groundwater transport, the characteristics of the waste, and site stability. We also looked at the basis and the context for other numbers that were -- have been used in waste management programs.

So the first area I will talk about is this near-surface stability, and near-surface disposal is not geologic disposal. It has much more challenging stability issues.

The climate cycling is pretty well known or expected. This value of 10,000 years that we could apply is more likely to be in a period of climate transition. We wanted to include -- in the end, we decided we wanted to include climate cycling within this compliance period for long-lived waste, because it should encourage the disposal of long-lived waste at stable sites as opposed to unstable sites.

And the regulation is very clear. It says, "A cornerstone of disposal is stability." There was no intention in the low-level waste framework to ever take material that you were going to lose control of, or that was going to be released into the environment in a large fashion, regardless of whether that was going to happen at 100 years, 500 years, or 10,000 years, the framework was designed to handle low concentrations of long-lived waste and moderate to high concentrations of shorter-lived waste.

So if you are going to put other materials into the framework, you need the requirements to distinguish between when that action is appropriate and when it is not appropriate.

A second thing that we considered was the characteristics of the waste, and, in this case, the direction from the Commission, the rulemaking derived from depleted uranium. And as we talked about, depleted uranium has this long in-growth characteristics over long -- or has daughter in-growth characteristics over long periods of time.

This value of 20,000 years better captures what is happening with depleted uranium specifically than does 10,000 years. And you say, "Well, it's not much in the context of depleted uranium." Well, at 1,000 years, you are off by about a factor of 1,000 from where the depleted uranium concentration is and its daughters and what risk it could cause compared to where it ends up at the peak.

And I talked about uncertainties. You have a vast -- large amount of uncertainties.

MEMBER RYAN: "Vast" is the right word.

MR. ESH: Vast, better. Okay. Waste characteristics are something that you know pretty well. So you should, at a minimum, at -- when you are considering developing, say, a period of performance, consider the waste characteristics that you are trying to develop the regulation for. And this regulation is to apply to depleted uranium.

When you are at 20,000 years, you are getting close to a factor of 10 for depleted uranium. And I think I can get in front of stakeholders and talk about uncertainty and say, "I'm doing the right thing when I'm only off by a factor of 10." I don't know how I'd make that argument when I'm off by a factor of 1,000 when we know what the characteristics of the material is.

So I think that argues -- in our mind, it argued for a period of around 20,000 years would help us accomplish that.

MEMBER RYAN: I guess the one thought I'd offer -- and I'm sure we can talk about it more next time -- is that that is one element of what --

MR. ESH: That's one. We have a few elements that we considered. We --

MEMBER RYAN: But there's a hundred more to think about.

MR. ESH: Well, there may be lots of others to think --

MEMBER RYAN: Lots of others.

MR. ESH: There may be lots of others to think about, but, like I said, this wasn't done in a vacuum. We did a detailed literature review of what is done internationally and in various programs. And I think we are pretty much in alignment with that.

The Europeans generally would say, "We should be going way out longer for these types of materials than this 20,000 years." They are much more comfortable going out to long timeframes, and they generally do, whether it's for radiological materials or industrial materials.

MEMBER RYAN: But by the same token, they end up backing up into an inventory limit for a site.

MR. ESH: Well, that's the point. If you don't develop the appropriate criteria to identify when you need an inventory limit, then how are you going to generate -- how are you going to develop the right inventory limit?

They used this criteria to develop inventory limits and assure, regardless of when it gets to people, they are going to limit it to what they want to limit it to. And I would argue that we need at least 20,000 years to develop the -- for the analysis to be done to determine those inventory limits for this type of material.

MEMBER RYAN: That's a whole different system than a concentration-based waste system.

MR. ESH: Well, the concept of inventory

limits is not new in this regulation. It exists in the regulation. It's very clear for long-lived waste that they expect that inventory limits would be generated when needed. The question becomes how you develop those inventory limits.

And what I'm saying is the period of performance is one of those things that you need to tell you what analysis to do to develop the inventory limit.

So on this Slide 24 it's a bit complicated. This is really a three-dimensional table. But what I'm trying to show you here is how the change in period of performance would affect which radionuclides you expect to see under different conditions.

So if you look at, say, the upper right-most box in the table, what that is showing is that at a deep arid site, at 10,000 years, you are probably not going to see much of these radionuclides. As you go to 20,000 years, or 50,000 years, then you capture them within your analysis.

VICE CHAIRMAN ARMIJO: I'm missing the time scale. That's what I was looking for.

MR. ESH: The time is embedded in the results of this analysis. This is the delta of the --

of what radionuclides that you capture in your compliance analysis as you go from 10- to 20,000 or 50,000. So the time is reflected in what nuclides show up in which boxes of these -- of this table.

VICE CHAIRMAN ARMIJO: Can I see the time -- can I get the time from a color code? I'm trying to find out where the time -- where I get the timeframe.

MEMBER RYAN: It's not on there.

MR. ESH: The time is not on there. The time -- like, for instance, if the time was -- if I set this at 1,000, all of these radionuclides would not be in any of the boxes. Well, actually, the technetium, tritium, chlorine would probably show up at the humid, shallow site, maybe iodine.

MEMBER RYAN: Carbon, iodine.

MR. ESH: Maybe carbon. But, almost definitively, things like strontium, neptunium, and everything on the other sides of those diagonals would not show up in your analysis.

MEMBER BLEY: So you could have a series of these is what you're saying. So this one is at a 1,000 --

MR. ESH: This is to show the delta for going longer from 10,000. I could also make a similar thing to going shorter to 1,000. But based on the waste characteristics, we didn't really consider strongly the --

MEMBER BLEY: Well, that's why I'm having trouble. You said the delta. I could see how this would be what's there at one time period, but the delta -- this is --

MR. ESH: This shows more of what you capture in the analysis as you -- as I would change the period of performance from 10,000 to 20,000 --

MEMBER BLEY: Yes.

MR. ESH: -- this shows what would show up under these particular conditions. On the upper --

MEMBER RYAN: That wouldn't have been -- the way you explained it before is things above the blue line and below the blue, if you look, you go from sites with fast water flow in the lower left to sites with slow water flow in the upper right.

MR. ESH: Yes.

MEMBER RYAN: And as you go out in time, things go from -- if I remember right, David, things go below the line.

MR. ESH: The lines are like this. So these are classes of radionuclide at given site conditions. So say you have a deep, arid site, the transport times are really, really long for a deep, arid site. So things like technetium, tritium, and chlorine might not even show up in 10,000 years. As you go to 20-, you start seeing them. Okay?

But if I go to the box in the other part of the corner, other part of the table down here, at a shallow, humid site, zirconium, thorium, and cesium show up as I go from 10 to 20. But if I'm shorter than 10,000, they don't even show up at the shallow, humid site. They are off the table, basically.

There are some things -- radium, lead, and americium -- that don't show up under any conditions.

MEMBER RYAN: David, we're going to have to wrap up real soon.

MR. ESH: The reason --

MEMBER RYAN: In the next minute or so.

MR. ESH: Yes, okay. The reason why -- this is -- this table is actually 25 elements analyzed for nine conditions probabilistically. There's essentially 225 horsetail plots, is what we call in our probabilistic analysis, that represent the information in this table. So it's understandable that it's a little hard to get your hands around.

MEMBER RYAN: Okay.

MR. ESH: The basis for our no dose limit for the second tier is we -- as I have talked about in detail, we think they can put them in the -- better put them in their proper context. We are better aligned with long-term decisionmaking in other programs, so you can argue that we're not aligned at all, but at least it's stepping in the right direction, and it's not inconsistent with past Commission policy of how they do waste disposal analysis.

And we can better align the impacts with the uncertainties as opposed to -- because I think it is reasonable to expect you should be able to generate, with a proper amount of model support and technical basis, that my range of impacts are maybe one to 100. You can't say that it's 23.7 at year 20,000, but you should be able to say what band you're in, whether it's -- I'm at a million millirem or one millirem.

But it is impractical to think that you are going to be able to say it's 23.7 definitively at year 47,000, so that's why we think it's better aligned with the uncertainties.

Now, we did develop guidance on this, and we think it's risk-informed, performance-based. What we basically say in our guidance is we allow people the flexibility, if you only have short-lived waste, or you have low concentrations of long-lived waste, just run the crank on your analysis and generate the numbers and explain that.

There is no additional regulatory burden associated with it if you have short-lived waste or low risk. The additional regulatory burden only comes in when you have large concentrations of long-lived waste.

That is the approach that we're dictating by this 20,000 period, which is a common metric for all in the regulation, but then allowing for some flexibility in how you -- what -- because in risk-informed, performance-based regulation, it really boils down to how much information you need to supply for different things.

And what we're saying is for the low-risk things you are not going to have to supply a lot of information. For the high-risk situation, you are going to have to supply a lot of risk.

And then, the Subcommittee talked about this Option 4 a little bit. This is just a backup slide on it would be a three-tiered approach. It is more complicated. We thought it would be difficult to get that through stakeholders, so --

MEMBER RYAN: Okay.

MR. ESH: So 15 seconds for discussion.

(Laughter.)

DW*: We've still got another whole presentation.

MEMBER RYAN: Mr. Chair, I defer to your --

CHAIRMAN ABDEL-KHALIK: We can give you five minutes.

MR. CARRERA: I can wrap it up in five minutes.

CHAIRMAN ABDEL-KHALIK: Thank you.

MR. CARRERA: Just a few slides. Okay. Let's move on to happier thoughts here. We are going to talk about stakeholder comments on the preliminary proposed ruling which you are aware the NRC published the Part 61 preliminary proposed rule language on regulations.gov and solicited early public comments on these documents.

We also held a public meeting on May 18th as well to solicit public comments. And the public comment period ended on June 18th, and the staff is in the process of doing a review on these comments.

Next slide, please.

We received about 30 verbal comments from the May 18th public meeting, and 125 comments at the end of the comment period on June 18th. And the comments came from a diverse group of stakeholders, public interest groups, industry, government organizations, and these are, as Dave mentioned, just as diverse as the organization that they represent.

This is just to give you a flavor of what -- the types of comments that we received. You know, as Dave mentioned, like, you know, a period of performance -- how people feel about it, you know, have a wide range of -- you know, some people approve, some people disapprove, and there are others that are in between that, you know, recommend maybe go to 10,000, 20,000, or somehow to taking a dose.

Dave covered the intruder assessment. What are the comments? Same thing -- there is a wide range.

Let's move on to the NRC Agreement State compatibility recommendations. Some comments suggest that we should recommend a strict compatibility level to ensure that the -- there is a consistency in the implementation of the regulation among the Agreement States, while I would suggest that we should work with the states, so that there would be no unintended consequences.

And we do have a representative from the State of Texas who represents the Organization of Agreement States and the CRCPD on the rulemaking team. So, you see, this -- let me try to wrap this up. It's a wide range of commenters and establishing a process of really analyzing them. And we will continue for the next several weeks to look at these comments with a magnifying glass to determine the extent that these comments will impact our rulemaking approach.

And that brings us to the path forward through this rulemaking.

Next slide, please.

This is the path forward. Following today's meeting, the staff will reevaluate the rulemaking approach in light of the comments received from you, the ACRS, as well as external stakeholders. However, the staff will not prepare responses to the comments received.

In August, the staff will come back and brief the ACRS Subcommittee on the changes to the rulemaking approach, as well as the guidance document. I know, Dr. Ryan, you are especially interested in that.

MEMBER RYAN: Yes.

MR. CARRERA: And at the same time, the

staff would like to make known that we would request a letter from the ACRS.

MEMBER RYAN: No problem.

(Laughter.)

Be happy to provide one.

MR. CARRERA: Thank you. And following the September ACRS briefing and the letter, staff will finalize the proposed rule document and guidance document. And if the Commission approves, they will make publicly available for comment, after which staff will return to brief the ACRS Subcommittee, and the subsequent full Committee, on the comments that we received from the proposed rule.

So that's -- if you have any more questions, please ask Dave.

(Laughter.)

MEMBER RYAN: Thank you, Andrew. And I want to say a vote of appreciation to David for, you know, having two hours of intense conversation. And I think at some point the NRC should give you another Ph.D. for all the hard work you have put in.

And I want to thank your colleagues on the Performance Assessment Team for all of the hard and quality work they have done. So we really appreciate your coming and talking in detail with us today. It's very helpful, I think, for some of the other members to learn a little bit more about this and gain some insights from the conversation. So thank you very much.

MR. ESH: Thank you.

CHAIRMAN ABDEL-KHALIK: Thank you.

MEMBER RYAN: Mr. Chairman, back to you.

CHAIRMAN ABDEL-KHALIK: Thank you. At this time, our schedule calls for us to take a 15-minute break. We are off the record for the day, and we will reconvene at 10 after.

(Whereupon, at 3:55 p.m., the proceedings in the foregoing matter went off the record.)

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Introduction to NRC Staff Review of NEDC-33173P, Supplement 2

"Analysis of Gamma Scan Data and Removal of Safety Limit Critical Power Ratio (SLMCPR) Margin"

Steve Philpott

NRR/DPR/PLPB

Interim Methods Process

- IMLTR SE imposes 24 limitations for EPU and MELLLA+ applications
- GE-Hitachi Nuclear Energy (GEH, previously GE) has committed to provide additional data to address several limitations as supplements to the IMLTR

IMLTR Supplement 2 Overview

- IMLTR SE Limitation 4: +0.02 adder to cycle-specific SLMCPR for EPU
- IMLTR SE Limitation 5: +0.03 adder to cycle-specific SLMCPR for MELLLA+
- Supplement 2 requests removal of Limitations 4 and 5
- No other changes in SE Limitations

Final Methods Roadmap

- **Supplement 2 (SE Appendix I)**
  - GEH commitment to qualify the nuclear methods (MFN 06-434)
  - Pin and bundle gamma scan data submitted August 14, 2009
  - Supplement 2 is in 3 parts and aims to remove the SLMCPR adders

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Supplement 2: Gamma Scan Data

- Bundle gamma scan data from Cofrentes
- Pin-wise gamma scan data from FitzPatrick
- To address additional margins for power distribution uncertainties for EPU / thermal margin for MELLLA+
- Does not request removal or modification of any IMLTR limitations other than Limitations 4 and 5

- BACKUP SLIDES

Background

- Jan 2002 - MELLLA+ LTR submitted
- Sep 2003 - VYNPS EPU LAR submitted
- Jun 2004 - BFN1 EPU LAR submitted
- Nov 2005 - M+LTR Rev. 2 submitted
- Feb 2006 - Interim Methods LTR submitted
- Sep 2007 - M+LTR approved
- Jan 2008 - IMLTR SE issued 1/08

Final Methods Roadmap

- GSTRM Part 21 (SE Appendix F)
  - Staff audited revised GE14 compliance documents to address findings related to the GSTRM Part 21 evaluation.
- Outstanding methods-related RAI responses (SE Appendix G)
  - GEH committed to address outstanding methods RAIs

Final Methods Roadmap

- Supplement 1 (SE Appendix H)
  - GEH commitment to qualify the void-quality correlation (MFN 06-435)
  - Pressure drop data and COBRAG analyses – submitted in April 2010
  - Supplement 1 data provided with intent to remove the OLMCPR 0.01 adder

Final Methods Roadmap

- IMLTR RAI 9 (SE Appendix J)
  - GEH committed to provide plenum fission gas and fuel exposure gamma scans (MFN 06-481)
  - To be submitted as a supplement to the PRIME LTRs
  - NRC Staff will examine to confirm the commitment has been satisfied

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Final Methods Roadmap

- Supplement 3 (SE Appendix K)
  - IMLTR restricted to GE14 and earlier GE fuel
  - Supplement 3 extended approval to GNF2 fuel
- Supplement 4 (SE Appendix L)
  - GEH committed to migrate to PRIME T-M methods (MFN 09-143)
  - Supplement 4 describes a process for migration
  - SE Appendix L will be supplemented by an NRC audit of the final implementation

Final Methods Roadmap

- IMLTR SE Limitation 23 (SE Appendix M)
  - MELLLA+ eigenvalue tracking data for first MELLLA+ plant
  - Monticello MELLLA+ LAR submitted Jan 2010 (licensee intends to comply with this limitation)
- IMLTR SE Limitation 13 (SE Appendix N)
  - Supplement required for application to gadolinia loading greater than 10 weight percent.

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NRC Staff Conclusions for NEDC-33173P, Supplement 2

"Analysis of Gamma Scan Data and Removal of Safety Limit Critical Power Ratio (SLMCPR) Margin"

Dr. Peter Yarsky

RES/DSA/RSAB

IMLTR Supplement 2 Overview

- IMLTR SE Limitation 4: +0.02 adder to cycle-specific SLMCPR for EPU
- IMLTR SE Limitation 5: +0.03 adder to cycle-specific SLMCPR for MELLLA+
- Supplement 2 requests removal of Limitations 4 and 5
- No other changes in SE Limitations

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Review Basis and Approach

- NRC staff reviewed:
  - Gamma scan data collection and processing
  - Gamma scan results
  - TIP data and comparisons to expanded EPU database
  - Comparison of key operating parameters
  - LPRM calibration uncertainty
  - Applicability to MELLLA+ operation

Conclusions

- Limitations 4 and 5 of the NRC staff's SE for the IMLTR impose adders to the cycle-specific SLMCPR values:
  - +0.02 for EPU operation
  - +0.03 for MELLLA+ operation.
- GEH requested that the NRC review and approve the NEDC-33173P, Supplement 2, Parts 1-3, and Revision 2 - to remove Limitations 4 and 5.

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Conclusions

- Based on review of Supplement 2 and Revision 2, the NRC staff concurs with GEH's request with one exception:

  Limitation 5 stipulates that for operation at MELLLA+, including operation at the EPU power levels at the achievable core flow state-point, a 0.03 value shall be added to the cycle-specific SLMCPR value. The added value of 0.03 will now be reduce to 0.01. This adder may be removed if GEH submits MELLLA+ operation data, subject to NRC staff review and approval.

- BACKUP SLIDES

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Comments on Mechanical Behavior of Ballooned and Ruptured Cladding

Ken Yueh
Senior Project Manager

ACRS Meeting

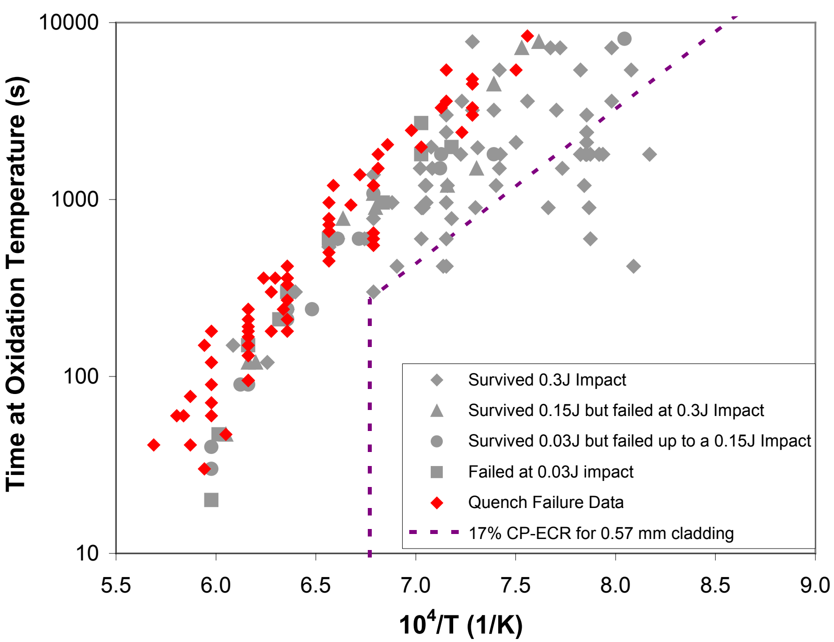
July 13, 2011

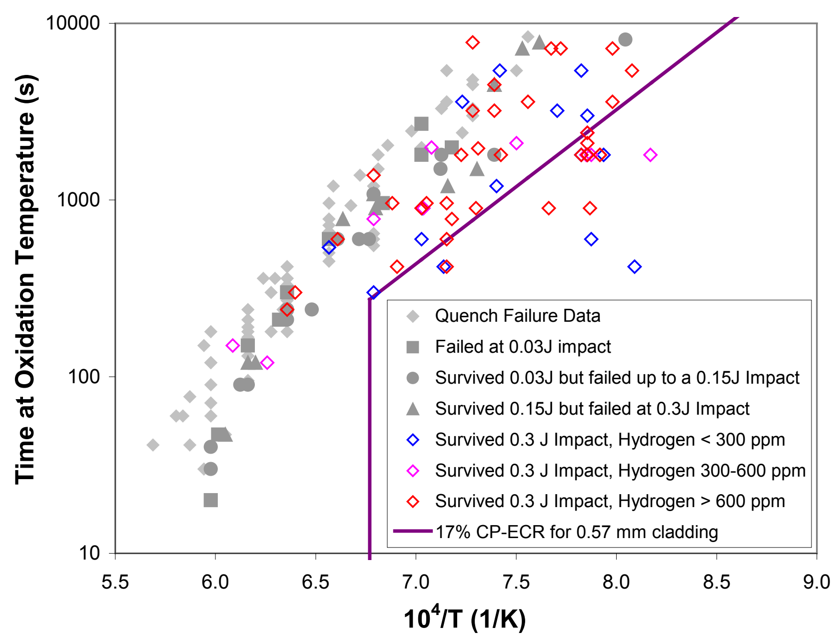
Feedback

- The industry is supportive of the NRC's research efforts on the mechanical behavior of the ballooned and ruptured cladding region
- The test results reported in ML111370032 are consistent with other international test results
  - Quench survivability with and without restraint
  - Mechanical strength and impact resistance are not as strongly dependent on hydrogen concentration in the hydrogen range of interest
  - International research efforts are focused on generating data to support alternative acceptance criteria not tied to ductility

Published Test Results Review

- Quench survivability and impact test results





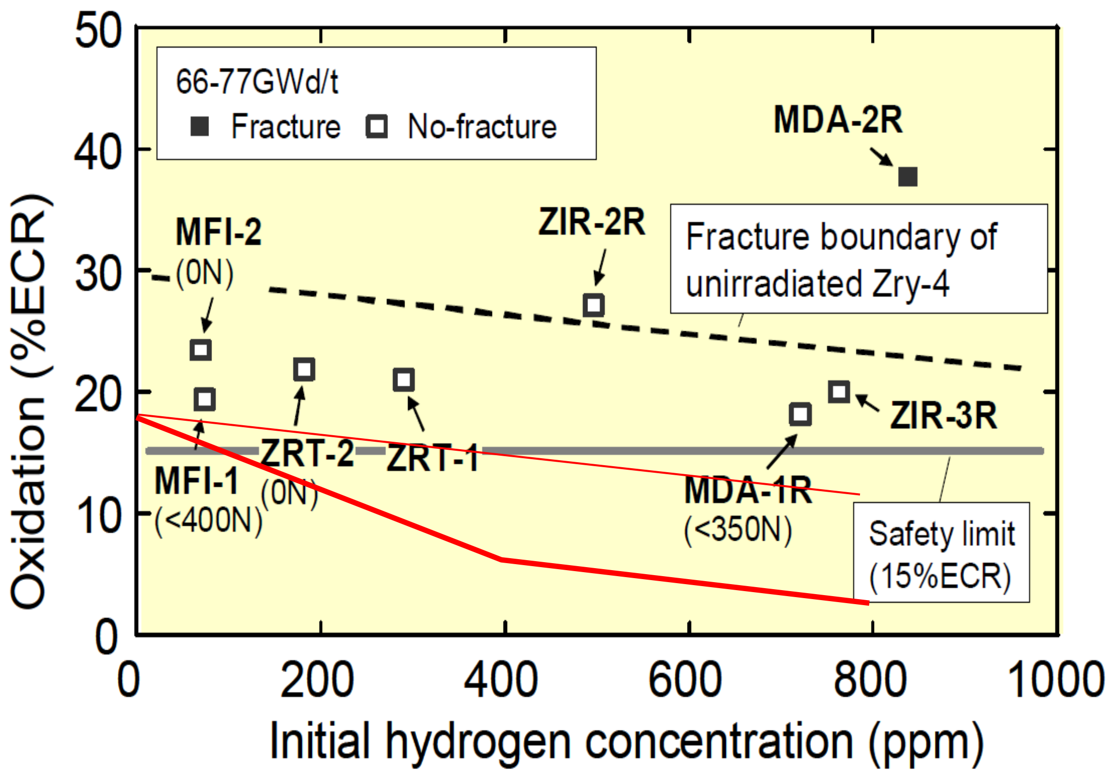
17% limit has a lot of margin to quench failure

No apparent hydrogen dependence

* Chung and Kassner, NUREG/CR-1344

Published Test Results Review

- Large margin to quench failure under axial restraint, hydrogen pre-charged and irradiated high burnup cladding



MFI-2 & ZRT-2:	no restraint
MDA-2R:	530N
ZIR-2R:	518N
ZRT-1 & ZIR-3R:	519N

JAEA Conclusion

"Fracture boundary is not reduced significantly by high burn-up and use of new alloys in the examined burnup level, thought it may be somewhat reduced with pre-hydriding as observed with unirradiated Zircaloy-4"

* Nagase, 2010 JAEA Fuel Safety Research Meeting

Feedback

- The application of the test results is not consistent with the principles of the proposed rule, which is based on the maintenance of ductility
  - Seems like an “exemption” is granted for the ballooned and ruptured region
  - Recommend the “ductility” requirement be placed in a lower level regulatory guide
- If the acceptance of the ballooned and ruptured region condition can be made on the basis of results documented in ML111370032, then the same standard should be allowed for the balance of the fuel rod

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Overview of the 10 CFR 50.46c Rulemaking

July 13, 2011

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

Meeting Purpose

- Present the expanded regulatory basis on regulatory treatment of the balloon region to ACRS

Meeting Agenda

1. Overview of 50.46c rulemaking activities

2. Additional research into mechanical behavior of the balloon

3. Industry remarks

4. ACRS discussion

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

Recent Developments

- Draft regulatory guidance developed
  - Presented to ACRS on May 10, 2011 (sub-committee) and June 8, 2011 (full committee)
- Staff continues to evaluate results of fuel fragmentation/dispersion research
- **"Mechanical Behavior of Ballooned and Ruptured Cladding"**

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Rulemaking Schedule

- Anticipated ACRS Meetings on Proposed Rule:
  - Sub-committee: December 2011
  - Full committee: February 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

10 CFR 50.46c ECCS Rulemaking: Mechanical Behavior of the Balloon

Advisory Committee on Reactor Safeguards
July 13, 2011

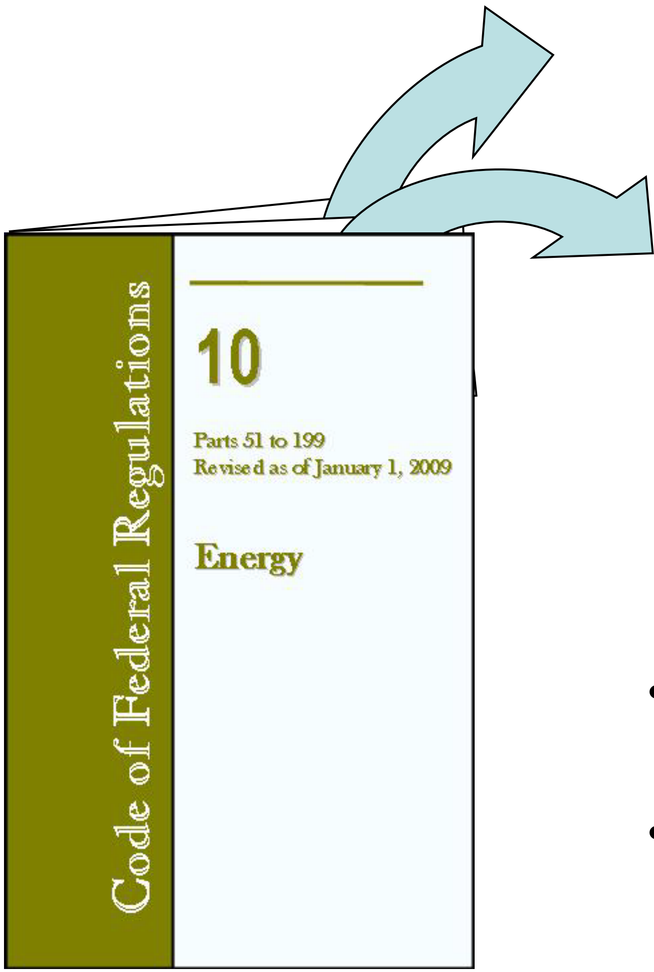
Michelle Flanagan
Michelle.Flanagan@nrc.gov
Division of Systems Analysis
Office of Nuclear Regulatory Research

Overview

Contents of *"Mechanical Behavior of Ballooned and Ruptured Cladding"*:

- Begins with a review of the regulatory history of the balloon region
- Presents the results of the NRC's integral LOCA research program
- Supports the treatment of the ballooned region within the rulemaking to revise 10 CFR 50.46(b).

Regulatory History



10CFR 50.46 Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors.

Appendix A of 10CFR Part 50, General Design Criteria 35 Emergency Core Cooling

Regulation requires that an emergency core cooling system is available to ensure that if a loss-of-coolant accident took place:

- The core remains amenable to cooling. **(Coolable geometry)**
- Decay heat is removed for the extended period of time required by the long-lived radioactivity remaining in the core (**Long-term cooling**)

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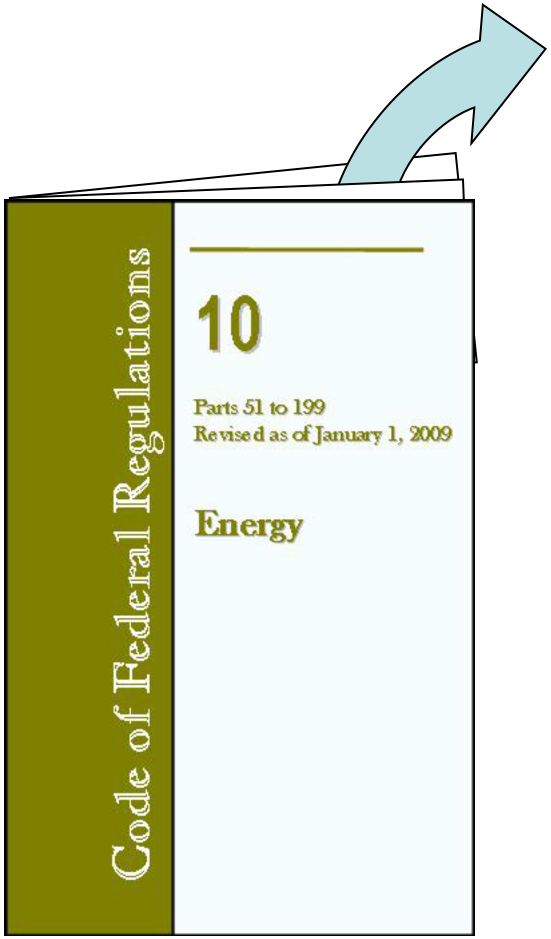
Regulatory History



§ 50.46 Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors.

Commission hearings in the 1970's established that coolable geometry could be maintained if the fuel **cladding remained ductile.**

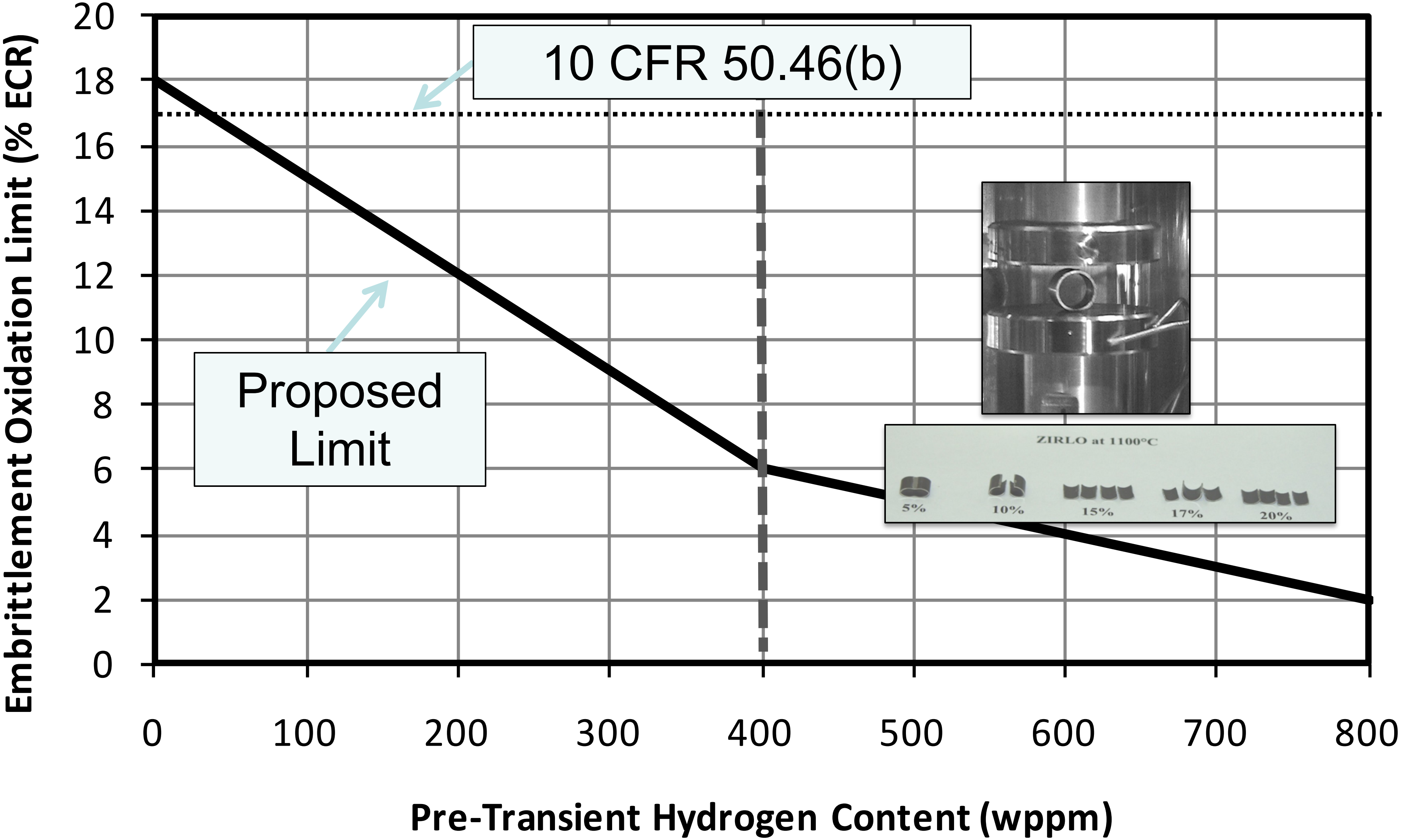
Therefore criteria were established, largely based on ring compression data, to ensure ductility, and these criteria are specified in the rule. The criteria state:

- The calculated maximum fuel element cladding temperature **shall not exceed 2200º F**.
- The calculated **total oxidation** of the cladding **shall nowhere exceed 0.17** times the total cladding thickness before oxidation.

Completed Investigation: Are these criteria still appropriate for high burnup cladding?

Finding: Completed embrittlement program indicated the oxidation criterion is not sufficient for high burnup cladding

Research Findings



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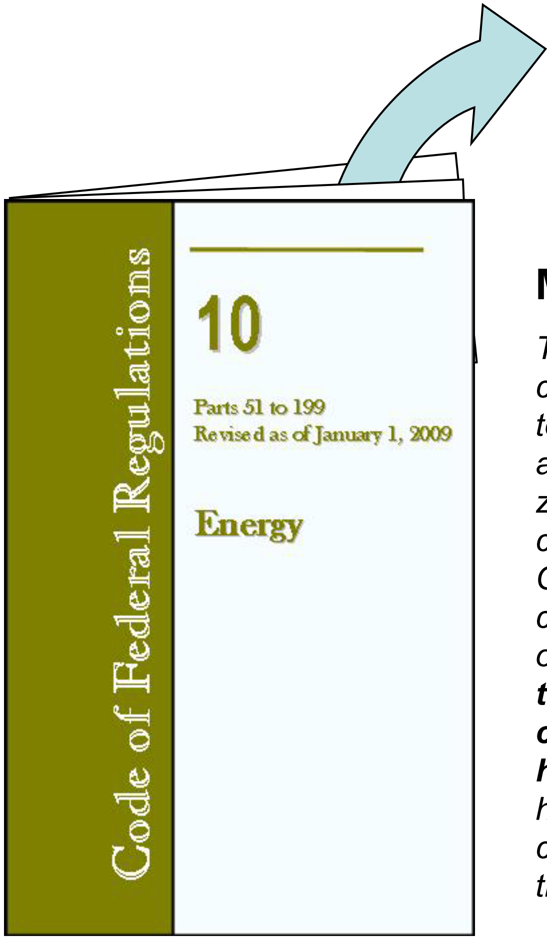
Existing treatment of the Balloon



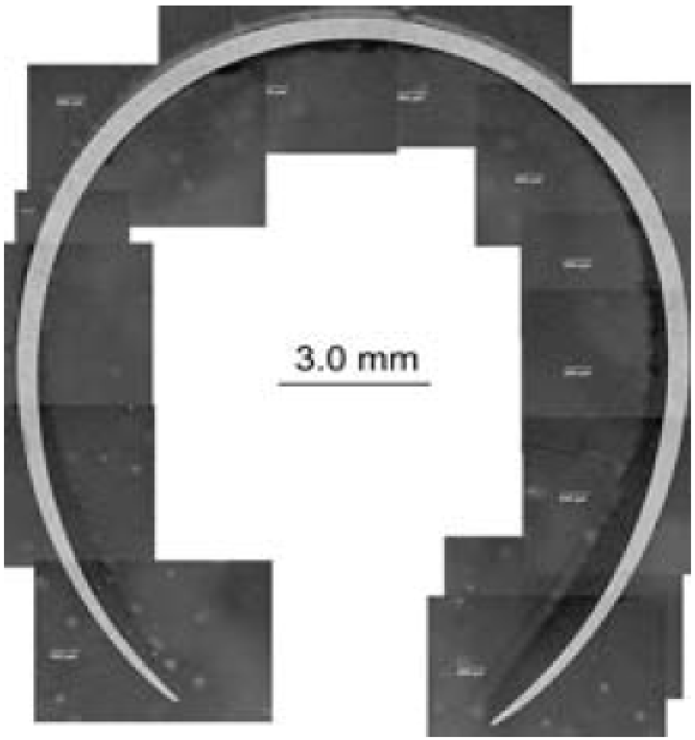
§ 50.46, "Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors"

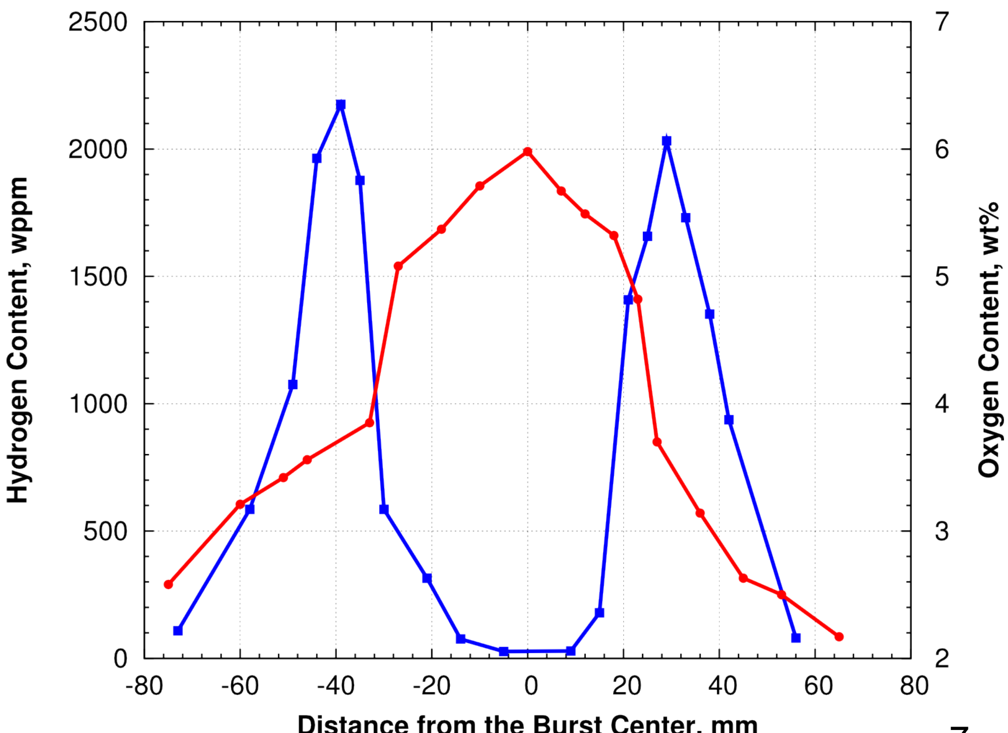
Maximum cladding oxidation is defined within the regulations:

The calculated total oxidation of the cladding shall nowhere exceed 0.17 times the total cladding thickness before oxidation. As used in this subparagraph total oxidation means the total thickness of cladding metal that would be locally converted to oxide if all the oxygen absorbed by and reacted with the cladding locally were converted to stoichiometric zirconium dioxide. If cladding rupture is calculated to occur, the inside surfaces of the cladding shall be included in the oxidation, beginning at the calculated time of rupture. Cladding thickness before oxidation means the radial distance from inside to outside the cladding, after any calculated rupture or swelling has occurred but before significant oxidation. ***Where the calculated conditions of transient pressure and temperature lead to a prediction of cladding swelling, with or without cladding rupture, the unoxidized cladding thickness shall be defined as the cladding cross-sectional area, taken at a horizontal plane at the elevation of the rupture****, if it occurs, or at the elevation of the highest cladding temperature if no rupture is calculated to occur, divided by the average circumference at that elevation. For ruptured cladding the circumference does not include the rupture opening.*

Is this approach still valid for the balloon node, with the new understanding of the effect of hydrogen?

Balloon Region Phenomenon



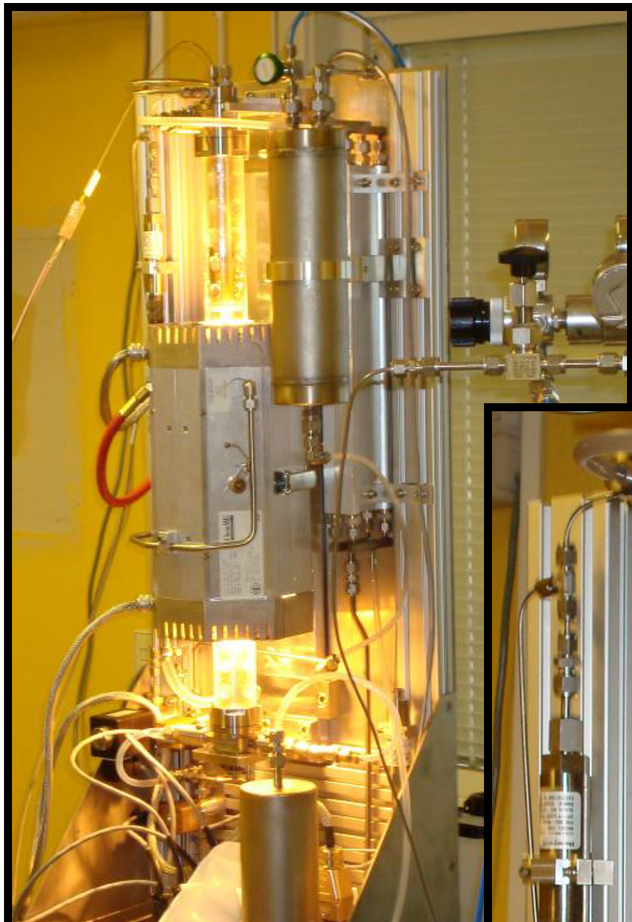


Proposed Treatment of the Balloon Region in RIL-0801

Research Information Letter-0801, *Technical Basis for Revision of Embrittlement Criteria in 10 CFR 50.46*

"Finally, no criteria have been found that would ensure ductility in the cladding balloon. However, loss of ductility in this short portion of a fuel rod should not lead to an uncoolable geometry as long as the amount of oxidation in the ballooned region remains limited in the current manner."

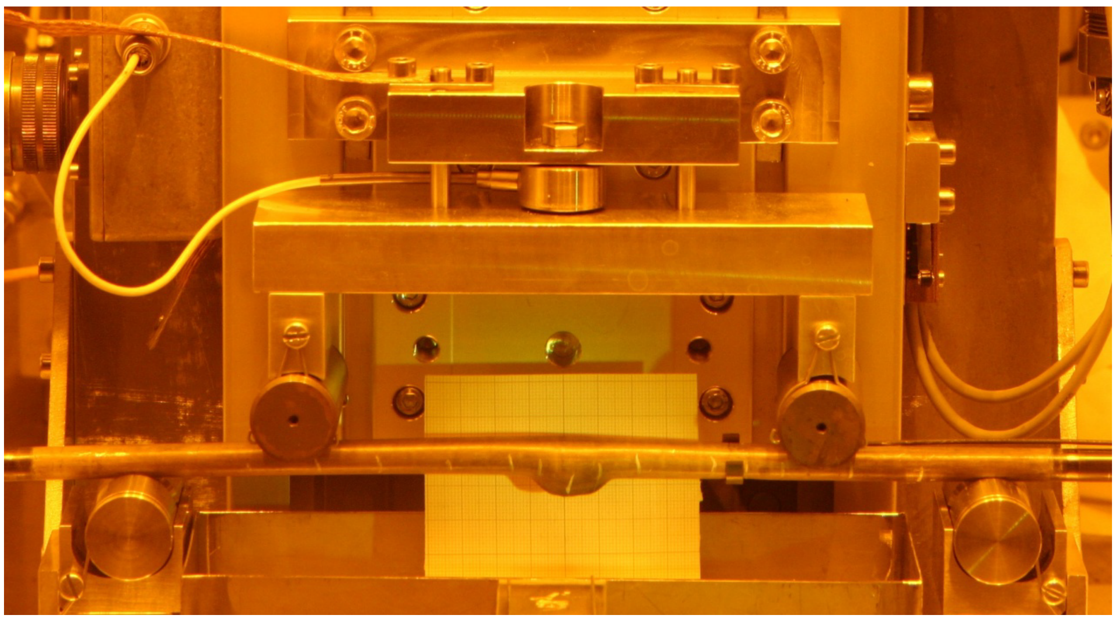
Investigation on Balloon Mechanical Behavior



Sections of pressurized, as-received, prehydrided and irradiated cladding, approximately 300 mm in length, were ramped from 300^{o}C at a rate of 5^{o}C/sec. They were pressurized to induce ballooning and burst and to target balloon sizes within the range of 30% - 70% strain. They were oxidized in steam to target oxidation levels (ECR), with consideration of the strain and hydrogen content.

The sections of cladding underwent ballooning, burst and oxidation in a test train shown to the left.

Investigation on Balloon Mechanical Behavior

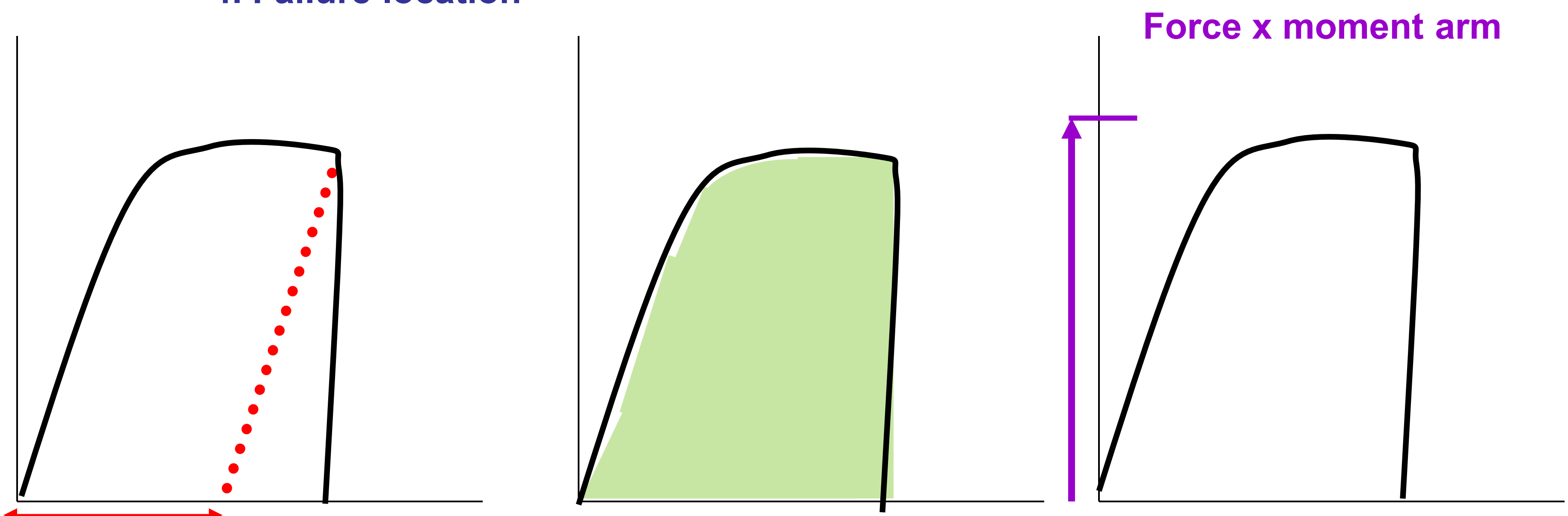


Bend tests were used to evaluate the balloon mechanical behavior ***in a mechanical test that applies a uniform bending moment to the ballooned region***. The axial location and nature of fracture was recorded. The observations of bend tests on irradiated material were compared to bend test results on as-received and pre-hydrided ballooned and burst integral samples run at ANL.

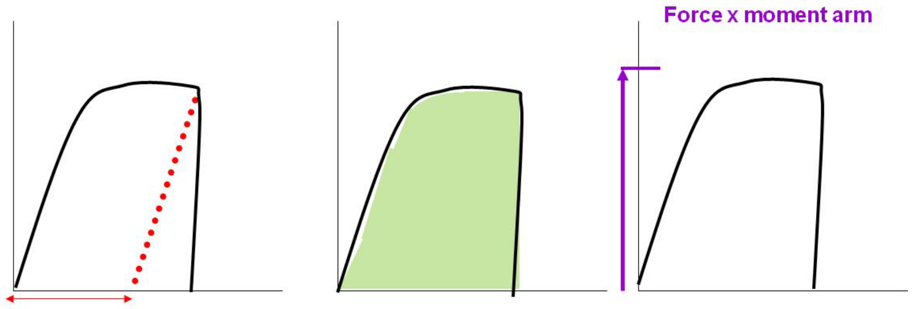
Investigation on Balloon Mechanical Behavior

Bend tests provide a variety of quantitative information, and are relatively sensitive to changing material properties

1. Maximum plastic displacement (measure of ductility)
2. Maximum applied energy (measure of toughness)
3. Maximum bending moment (measure of strength)
4. Failure location



Investigation on Balloon Mechanical Behavior



Investigate influence of:

- Oxidation
- Irradiation
- Balloon size
- Bend test temperature
- Hydrogen content

ANL

Studsvik

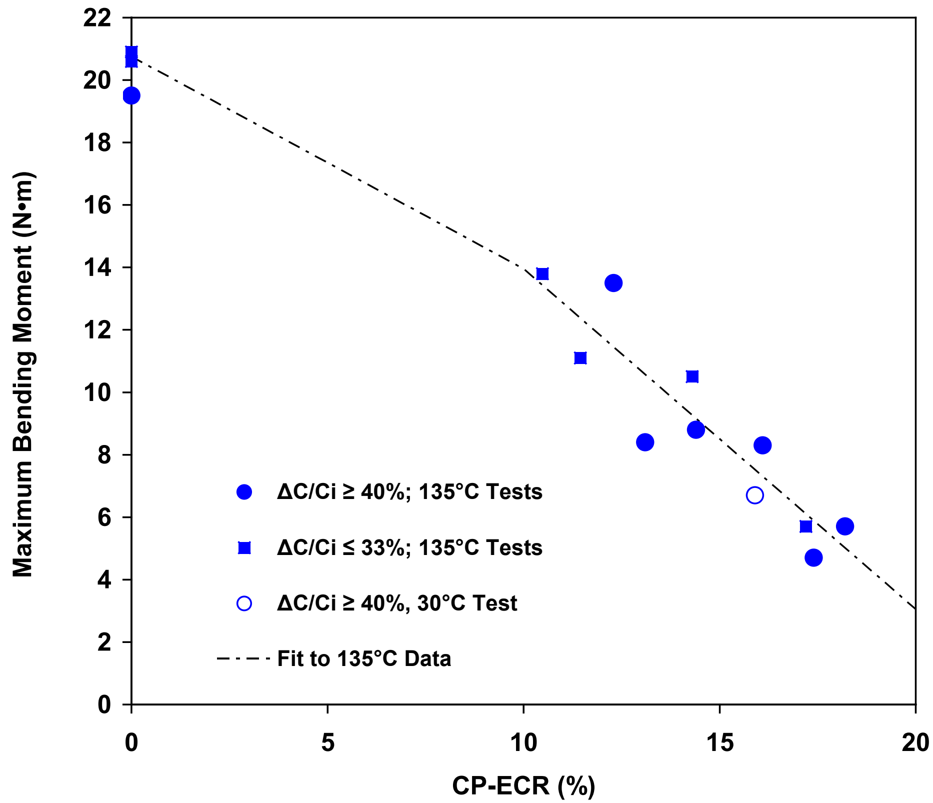
Results – As-Fabricated

Test ID OCZL#	Fill Pressure, psig	Rupture Strain, % (T_R, °C)	CP-ECR %	Quench at 800°C	Stress in Rupture Node	Failure Location	Maximum Bending Moment N•m	Maximum Energy J	Plastic Displace. mm
8	600	21 (845±25)	0	No	Maximum tension	No cracking	20.9	>8.4	>7.7
9	400	33 (875±15)	0	No	Maximum tension	No cracking	20.6	>8.3	>7.7
10	1600	69 (715±10)	0	No	Maximum tension	No cracking	19.5	>7.7	>7.1
12	1000	32 (805±20)	14	No	Maximum compression	-40 mm +33 mm	10.5	0.78	0
13	1200	41 (741±15)	14	No	Maximum tension	Rupture opening	8.8	0.58	0
14	1200	47 (735±6)	18	Yes	Maximum tension	Rupture opening	5.7	0.24	0
15	1200	51 (755±23)	18	Yes	Maximum compression	Cracking; no failure	8.9	>2.3	>13
17	1200	49 (750±17)	13	Yes	Maximum tension	Rupture opening	8.4	0.71	>0.5
18	1200	43 (748±4)	12	Yes	Maximum tension	Rupture opening	13.5	1.29	0
19	600	24 (840±12)	17	Yes	Maximum tension	+23 mm -23 mm	5.7	0.23	0
21	600	27 (850±10)	10	Yes	Maximum tension	+33 mm -29 mm	13.8	1.17	0
22[a]	600	22 (837±12)	11	Yes	Maximum tension	+25 mm -27 mm	11.1	0.83	0
25[a]	1200	42 (757±21)	16	Yes	Maximum tension	-26 mm +26 mm	8.3	0.50	0
29[a]	1200	49 (746±19)	17	Yes	Maximum tension	Rupture opening	4.7	0.40	>8.5
32[a,b]	1200	49 (748±8)	17	Yes	Maximum tension	Rupture opening	6.7	0.26	0

[a] Displacement rate lowered to 1 mm/s to get better agreement between bend and ring-compression tests for the maximum elastic strain rate.
[b] 4 -PBT conducted at 30°C.

Results – As-Fabricated

Bending Moment

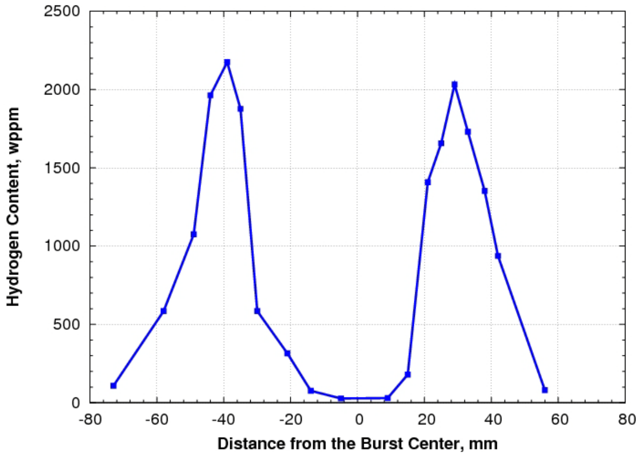


Maximum bending moment as a function of maximum oxidation level (CP-ECR) for post-LOCA samples subjected to 4-PBTs with the rupture region in tension for all tests but one. Bend tests were performed at 135°C and 2 or 1 mm/s to 14-mm maximum displacement. One bend test was performed at 30°C and 1 mm/s.

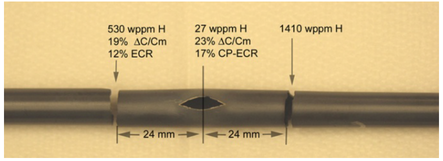
For ECR > 10%; M_{max} = 13.96 – 1.090 (CP-ECR – 10%), N•m

Results – As-Fabricated

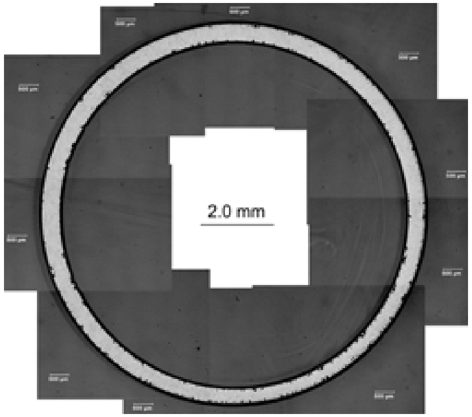
Failure Location



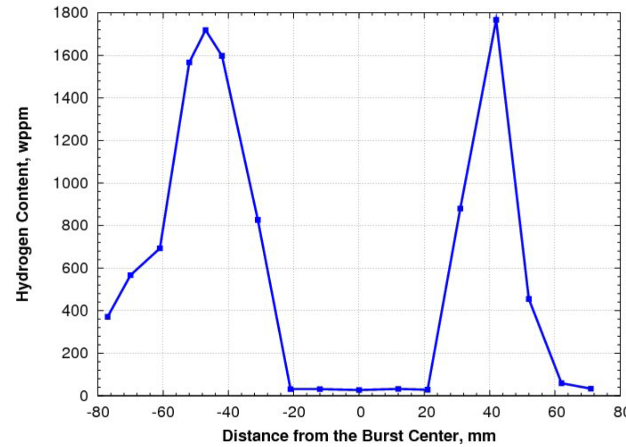
(a) Hydrogen-content profile



b) Measured values at failure locations

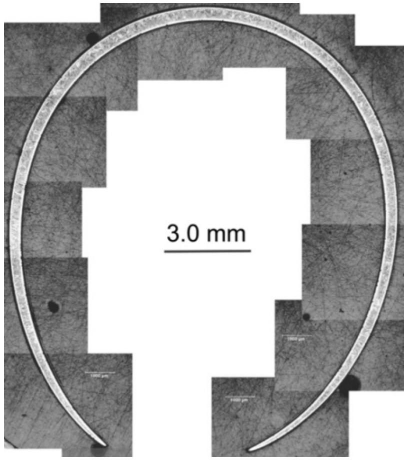


(c) Low-magnification image of severed cross section at -24 mm



(a) Hydrogen-content profile

(b) Failure location



(c) Low-magnification image of severed cross section

Results – As-Fabricated

Failure Energy

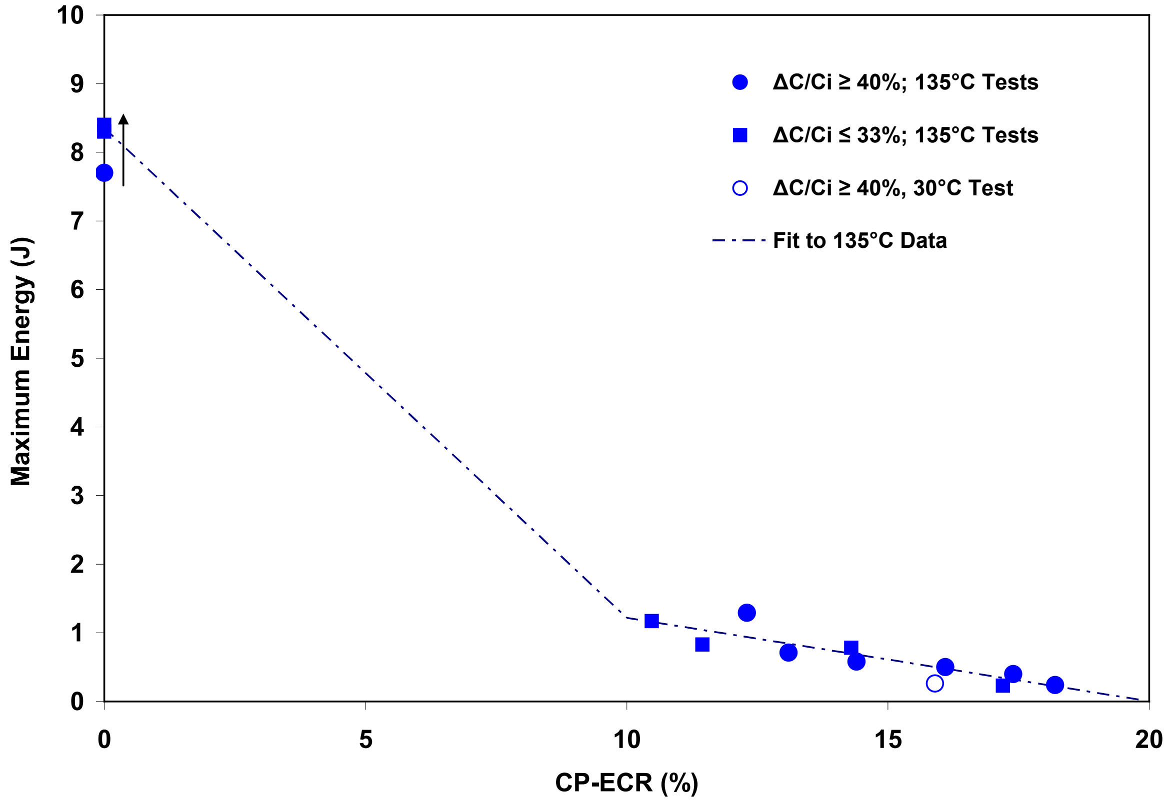
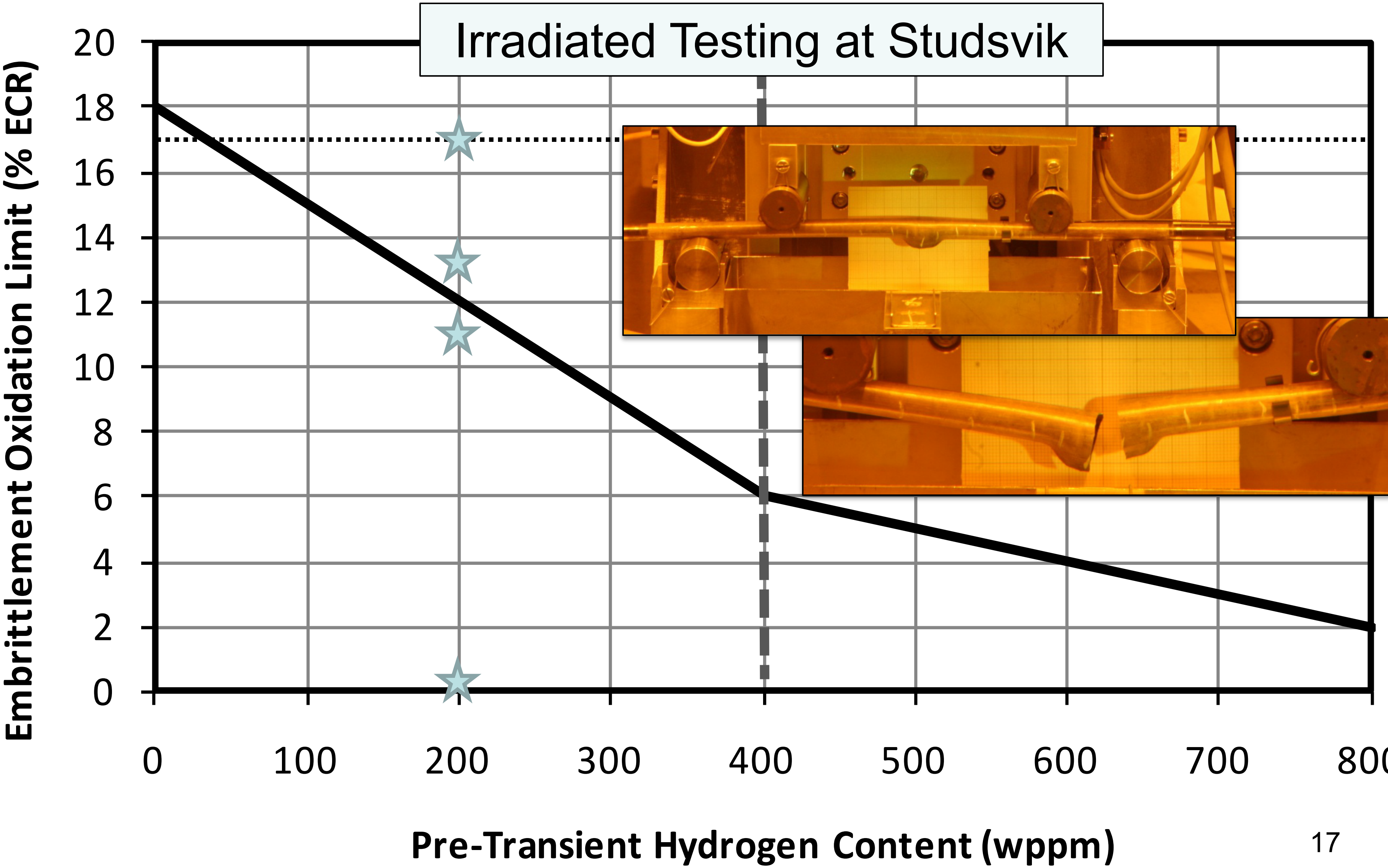


Figure 4. Maximum (for 0% CP-ECR) and failure (for ≥10% CP-ECR) energy as a function of oxidation level (CP-ECR) for post-LOCA samples subjected to four-point bending with the rupture region in tension for all tests but one. Bend tests were performed at 135°C and 2 or 1 mm/s to 14-mm maximum displacement. One bend test was conducted at 30°C and 1 mm/s.

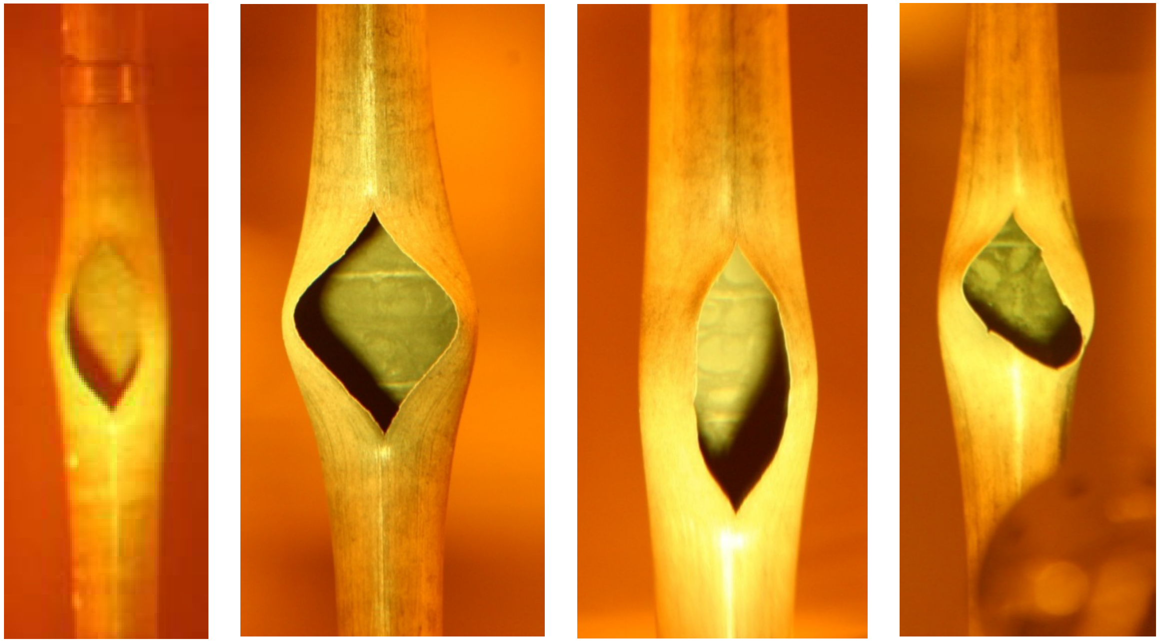
For ECR > 10%; E_{max} = 1.22 – 0.121 (CP-ECR – 10%), J

Investigation on Balloon Mechanical Behavior



Results – Irradiated Tests

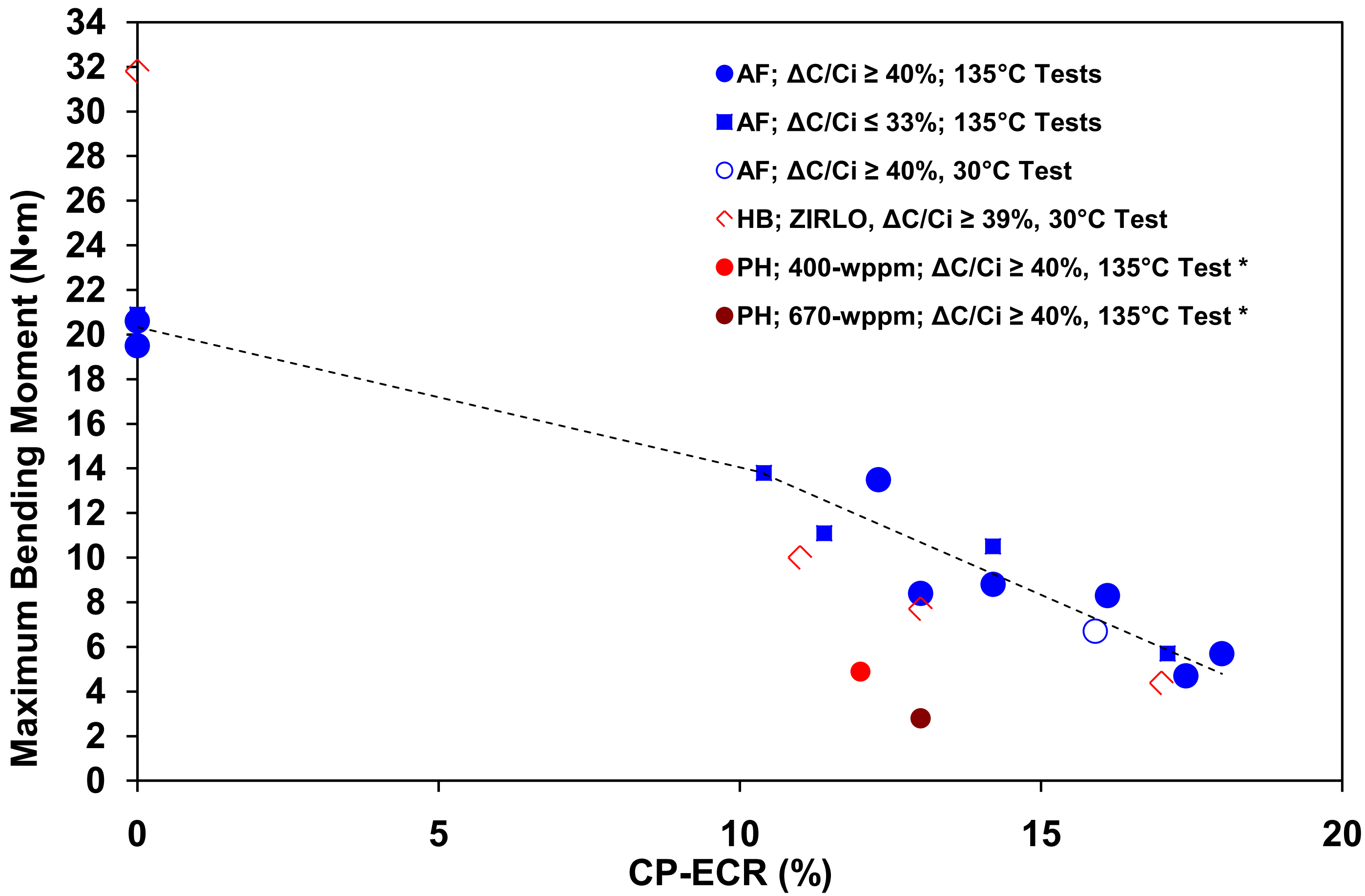
	189	191	192	193
Comments	Ramp to rutpure test	Ramp to PCT, held for 25s at PCT	Ramp to PCT, held for 5s at PCT	Ramp to PCT, held for 85s at PCT
Burnup	≈ 72 GWD/MTU	≈ 71 GWD/MTU	≈ 72 GWD/MTU	≈ 72 GWD/MTU
PCT	950 ± 20°C	1185 ± 20°C	1185 ± 20°C	1185 ± 20°C
Measured Strain	48%	50%	56%	50%
Calculated ECR	≈ 0%	13%	11%	17%
Fill Pressure	110	110	82	82
Burst Pressure	113	104	77	77
Burst Temperaure	700	680	700	728
Rupture Width	10.5	17.5	9.0	13.8
Rupture Length	23.9	21.6	22.7	17.8



(a) (b) (c) (d)

A close up of the rupture opening after the transient on rod segment from test (a) 189 (b) 191 (c) 192 and (d) 193

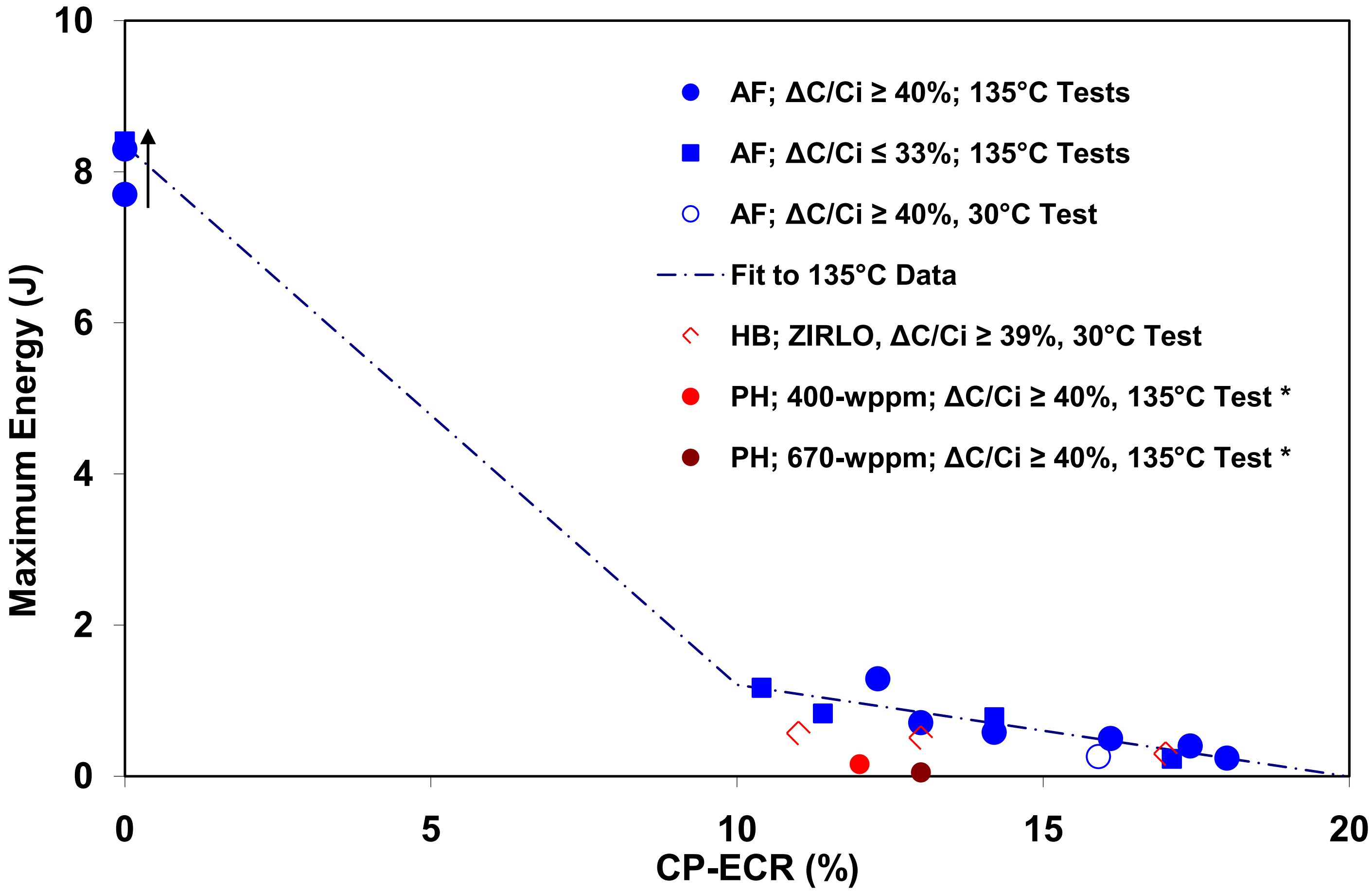
Results – Comparing AF, PH & Irradiated data



Maximum bending moment as a function of oxidation level for post-LOCA-oxidation samples subjected to 4PBTs at 1-2 mm/s and either 135°C or RT (30°C). For samples at 0% CP-ECR, which did not fail, values are plotted for 14-mm displacement. The trend line is a best fit to Argonne 4PBT data at 135°C.

* **NOTE:** The values for pre-hydrided material have become available since the DRAFT "Mechanical Behavior of Ballooned and Ruptured Cladding" report was transmitted to ACRS in support of this briefing.

Results – Comparing AF, PH & Irradiated data



Maximum energy as a function of oxidation level for post-LOCA-oxidation samples subjected to 4PBTs at 1-2 mm/s and either 135°C or RT (30°C). For samples at 0% CP-ECR, which did not fail, maximum energies through 14-mm displacement are plotted. For samples with >10% CP-ECR, data points represent failure energy. The trend line is a best fit to Argonne 4PBT data at 135°C.

* **NOTE:** The values for pre-hydrided material have become available since the DRAFT “Mechanical Behavior of Ballooned and Ruptured Cladding” report was transmitted to ACRS in support of this briefing.

Program Conclusions

- All samples survived quench
- The values of bending moment and failure energy have been shown to decrease with increasing oxidation, even through a wide range of values for balloon strain
- Even though very high values of hydrogen content were observed within the balloon region for the as-fabricated samples, no matter where the failure was observed, the residual bending moment remained a function of the oxidation
- The values of bending moment and failure energy reveal a hydrogen effect on the mechanical behavior of the balloon region that should be accounted for
- When the new proposed hydrogen-based criteria is applied in the rupture region, mechanical properties in this region are maintained to at least that of fresh cladding

Program Conclusions *within the Regulatory Context*

Addressed in three aspects

- Treatment of the ballooned region within the rulemaking to revise the embrittlement criteria in 10 CFR 50.46
- Extrapolation of research findings to new cladding alloys and lower oxidation temperatures
- Alternate performance metrics for the ballooned and ruptured region of a fuel rod

Program Conclusions

Within the Regulatory Context: Treatment of the Ballooned Region within the Rulemaking To Revise 10 CFR 50.46(b)

The time-at-temperature limit developed based on ring-compression data to limit oxidation should be applied uniformly to the entire rod, with the provisions for the balloon outlined in the existing rule to use the average wall thickness in the rupture region to calculate the CP-ECR.

Program Conclusions

Within the Regulatory Context: Extrapolation of Research Findings to New Cladding Alloys and Lower Oxidation Temperatures

- Embrittlement limits developed for *new cladding alloys or at lower oxidation temperatures* based on RCTs may be applied uniformly to the entire rod, with the provisions for the balloon outlined in the existing rule to use the average wall thickness in the rupture region to calculate the CP-ECR.

- Results did not reveal any reason that materials which demonstrate improved embrittlement performance in RCTs should not apply measured improvement in the balloon region
  - Yield properties and fuel rod dimensions considered in the conclusion

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Program Conclusions

Within the Regulatory Context: Alternate Performance Metrics for the Ballooned and Ruptured Region of a Fuel Rod

- There has been longstanding discussion of alternate metrics for fuel rod performance under LOCA conditions within the international community.
- Alternate approaches rely on detailed knowledge of LOCA loads or complex experimental and modeling research programs.
- The state-of-the art does not support regulatory positions based on these proposals in the near term and therefore, pursuing more complex performance metrics for ballooned and ruptured regions is not recommended at this time.

Proposed Update to RIL-0801

Research Information Letter-0801, *Technical Basis for Revision of Embrittlement Criteria in 10 CFR 50.46*

Finally, no criteria have been found that would ensure ductility in the cladding balloon. However, loss of ductility in this short portion of a fuel rod should not lead to an uncoolable geometry as long as the amount of oxidation in the ballooned region remains limited in the current manner. Bending moment and failure energy have been measured using the 4-PBT for as-received, pre-hydrided and irradiated samples to determine the resistance to fracturing and fragmentation of ballooned cladding during a LOCA. Values comparable to those determined for as-fabricated cladding at 17% CP-ECR have been found when oxidation is limited in accordance with embrittlement threshold shown in Figure 1.

Conclusion

- Completed integral LOCA test program has generated new data and understanding of the mechanical behavior of ballooned and ruptured fuel rods
- Results indicate that limiting oxidation in the balloon region continues to be appropriate
- Results indicate that applying the hydrogen-based embrittlement limit in the balloon region preserves mechanical behavior to that of as-fabricated rods at 17%
- A technical basis document has been written to supplement the treatment of the balloon within the proposed rulemaking
- Updates to RIL-0801 have been proposed which incorporate the findings of the recent research

10 CFR Part 61: Preliminary Proposed Rule Language

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585th Meeting of the Advisory Committee on Reactor Safeguards

July 13, 2011

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Purpose of rulemaking

- Emerging regulatory issues in LLW disposal
  - Discrepancies from original 10 CFR Part 61 assumptions
    - Disposal sites are currently faced with disposing of waste types that were not considered at that time
  - Uranium enrichment
    - More than 1 million metric tons of depleted uranium (DU) require disposal
  - Industry innovation to address Class B & C LLW
    - Industry contemplating large-scale blending

Commission Directions

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- SRM-SECY-08-0147:
  - Require site-specific analysis for disposal of large quantities of DU
  - Meet performance objectives
  - Specify criteria needed for analysis
  - Develop supporting guidance
- SRM-SECY-10-0043:
  - Incorporate blending issue into the existing rulemaking for DU

DU + Blending

Proposed Amendments to Part 61 Regulations

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- Site-Specific Analyses:
  1. Performance assessment — to demonstrate compliance with the protection of the general population from releases of radioactivity performance objective (§ 61.41)
  2. Intruder assessment — to demonstrate compliance with the protection of inadvertent intruders performance objective (§ 61.42)
  3. Long-Term analysis — to demonstrate how the design of the facility considers the potential long-term radiological impacts (§ 61.13 (e))
  4. Update analyses at facility closure — to be updated and included with any application to amend the license for closure (§ 61.13 (e))

Proposed Amendments to Part 61 Regulations (continued)

- Other Supporting Changes:
  1. New definitions, concepts, and long-term analysis
  2. Use of total effective dose equivalent (TEDE)

- Waste-Stream Neutral:
  1. Site-specific-analyses requirements would apply to all wastes

Site-Specific Analyses: Performance Assessment

- § 61.41 Protection of the general population from releases of radioactivity.

    Revised requirements:

    § 61.41(a)—Revised to include TEDE.

    § 61.41(b)—Added requirement to demonstrate compliance with a performance assessment for 20,000 years.

Site-Specific Analyses: Intruder Assessment

- § 61.42 Protection of inadvertent intruders.

  Revised requirements:

  § 61.42(a)—Added annual dose of 500 mrem TEDE.

  § 61.42(b)—Added requirement to demonstrate compliance with a intruder assessment for 20,000 years.

Site-Specific Analyses: Long-Term Analysis

- § 61.13 Technical analyses.

  New requirements:

  § 61.13(e)(1)—Discuss how the design of the facility considers the potential long-term radiological impacts, consistent with available data and current scientific understanding.

  § 61.13(e)(2)—Calculate the peak annual dose that would occur 20,000 or more years after site closure. No dose limit applies to the results of these analyses.

Site-Specific Analyses: Updated Analyses

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- § 61.28 Contents of application for closure.

  New requirement:

  § 61.28(a)(2)—Submit revised analyses for § 61.13 using the details of the final closure plan and waste inventory.

- § 61.52 Land disposal facility operation and disposal site closure.

  New requirement:

  § 61.52(a)(12)—Dispose of waste consistent with the description provided in § 61.12(f), and the technical analyses required by § 61.13.

Other Supporting Changes

- § 61.2 Definitions.

  New definitions:

  intruder assessment, long-lived waste, and performance assessment.

- § 61.7 Concepts.

  New concepts:

  intruder assessment, performance assessment, and long-term analysis.

10 CFR Part 61: Stakeholder Comments on the Preliminary Proposed Rule Language

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July 13, 2011

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Stakeholder Comments

- May 18th Public Meeting (~ 30 specific comments, suggestions, and recommendations received)
- 15 Comment Letters (~125 specific comments, suggestions, and recommendations)
- Diverse Stakeholders (public interest groups, industry, Federal and States government organizations)

Stakeholder Comments (continued)

- Near-Surface Inappropriate for Disposal of DU
- 20,000-year Period of Performance
- Intruder Assessment Requirement
- NRC/Agreement State Compatibility Recommendations
- Guidance v.s Rule
- Rulemaking Oversteps SRM-SECY-08-1047
- Other

Path Forward

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- Following today's meeting, staff will re-evaluate rulemaking approach in light of comments received from ACRS and external stakeholders
- In August, staff will brief ACRS Subcommittee on any changes to rulemaking approach, and request letter from ACRS following September Full Committee meeting
- In September, staff will brief ACRS full committee on any changes to rulemaking approach
- Following September ACRS briefing and ACRS letter, staff will finalize proposed rule documents
- After Proposed Rule (and Guidance) is made publicly available for comment, staff will return for a briefing of the ACRS Subcommittee

10 CFR Part 61: Technical Issues for the Low-Level Waste Rulemaking

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585th Meeting of the Advisory Committee on Reactor Safeguards

July 13, 2011

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Main Topics

- **Intruder Assessment**
- **Period of Performance**

Intruder Assessment

Intruder Assessment

- Intruder assessment has three parts: waste classification and segregation, intruder barriers, and intruder dose assessment.
- New requirement for an intruder dose assessment.
- Necessary because the Commission directed the staff not to alter the waste classification system.
- Waste classified under 61.55(a)(6) could represent an unanalyzed condition from an intruder protection perspective.

Intruder Assessment

- Regulatory construct.
- Intruder assessment is supported by a variety of groups (IAEA, ICRP, NCRP).
- Evaluate potential exposure of inadvertent intruders after institutional control period (100 years).
- Dose limit of 500 mrem TEDE reflects NRC belief that exposures are unlikely, albeit possible, and impacts will be limited to a few individuals.
- Reasonably foreseeable land use scenarios, impacted by timeframe and change in natural site conditions.

Intruder Assessment

Intruder assessment is an analysis that:

(1) Assumes that an inadvertent intruder occupies the site at any time during the compliance period after institutional controls are removed and engages in activities (e.g., agriculture, dwelling construction, and resource exploration) that might unknowingly expose the inadvertent intruder to radiation from the waste;

(2) Examines the capabilities of intruder barriers to inhibit contact with the waste by an inadvertent intruder or to limit the inadvertent intruder's exposure to radiation; and

(3) Estimates the potential annual total effective dose equivalent, considering associated uncertainties, to an inadvertent intruder engaging in activities that might unknowingly expose the inadvertent intruder to radiation from the waste.

Period of Performance

Background

- Period of performance is one of many important elements in the safety evaluation of low-level waste (LLW) disposal.

- Different approaches are used within the US and internationally for LLW.

- Diverse views among stakeholders.

NRC Background

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- The Advisory Committee on Nuclear Waste (ACNW) commented on the period of performance on numerous occasions (since 1994).
- ACNW communicated basic principles (see next slide).
- Commission direction (SRM-96-103).
- NUREG-1573: Performance Assessment Working Group (PAWG) recommended 10,000 years with longer-term impacts in site environmental assessment.

ACNW Principles*

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- Two tiers:

Consider site-specific characteristics

Tier #1

- No less than time for more mobile radionuclides to produce peak dose.
- No longer than a time period over which scientific extrapolations can be convincingly made.
- If the disposal system fails to meet the standard during the specified time period, ameliorating actions should be required or the site should be rejected.

* from Pomeroy 1997

ACNW Principles*

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Tier #2

- Evaluate robustness of the facility over the range of external processes and events that may affect the performance of the facility over long time periods.
- This evaluation also will ensure that no significant changes in the dose from the disposal site will occur.
- Estimates of the peak dose from the facility beyond the time of compliance are qualitatively compared with the dose standard.

* from Pomeroy 1997

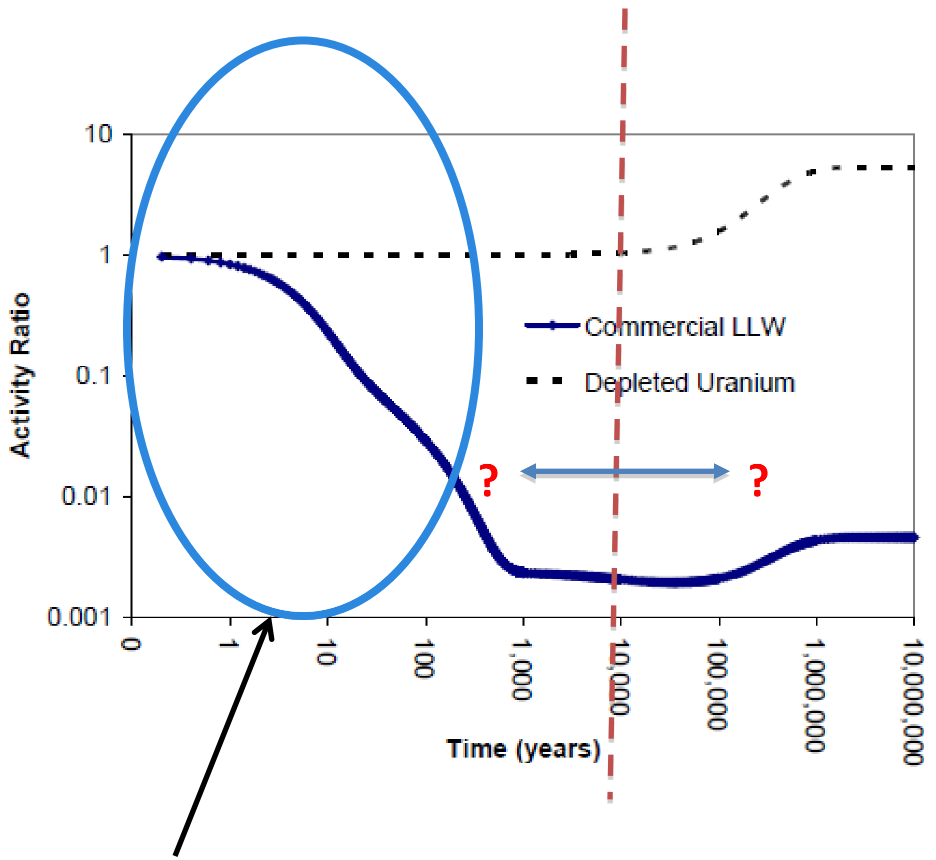
General Objectives

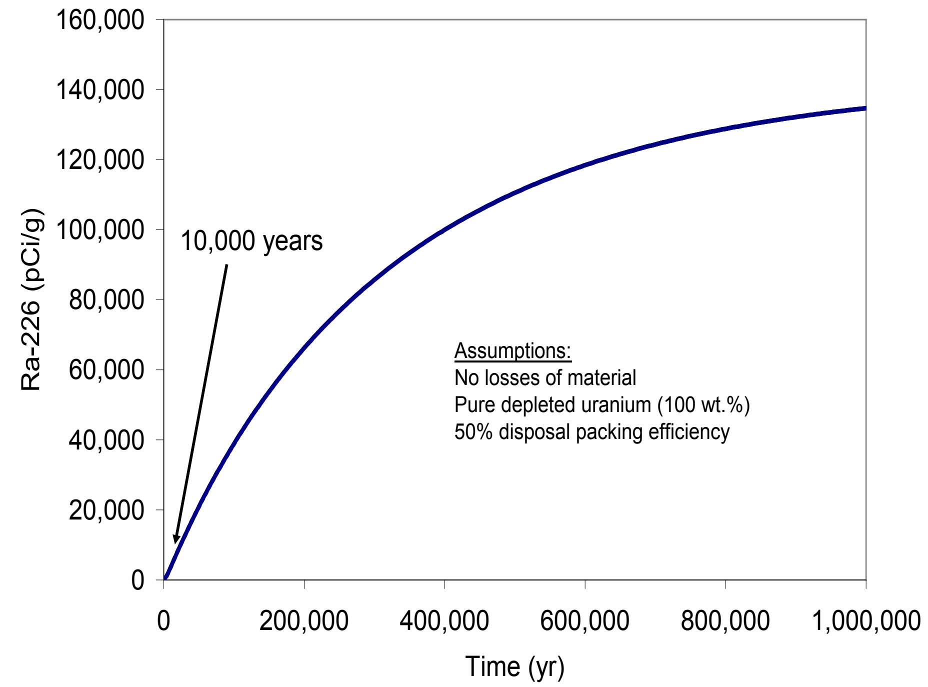
- Provide protection to present and future generations
- Consider uncertainties
- Communicate long-term impacts
- Facilitate decision making

Period of Performance Selection Process

- Literature review:
  - Characteristics of waste
  - Analysis framework
  - Uncertainties (societal, natural, engineering, technology)
  - Socioeconomic considerations (transgenerational equity, discounting)

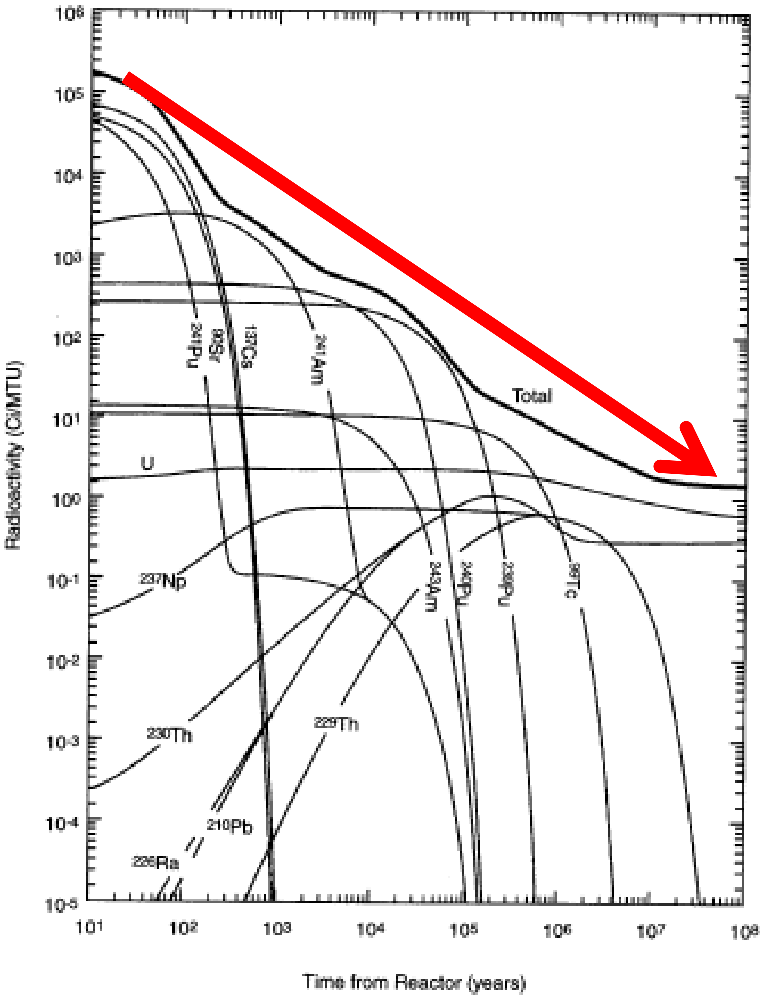
Waste Characteristics





This 99% of the waste does not cause risk from disposal

Waste Characteristics - HLW



From NUREG-1538

LLW Inventory Analysis – Rulemaking Context

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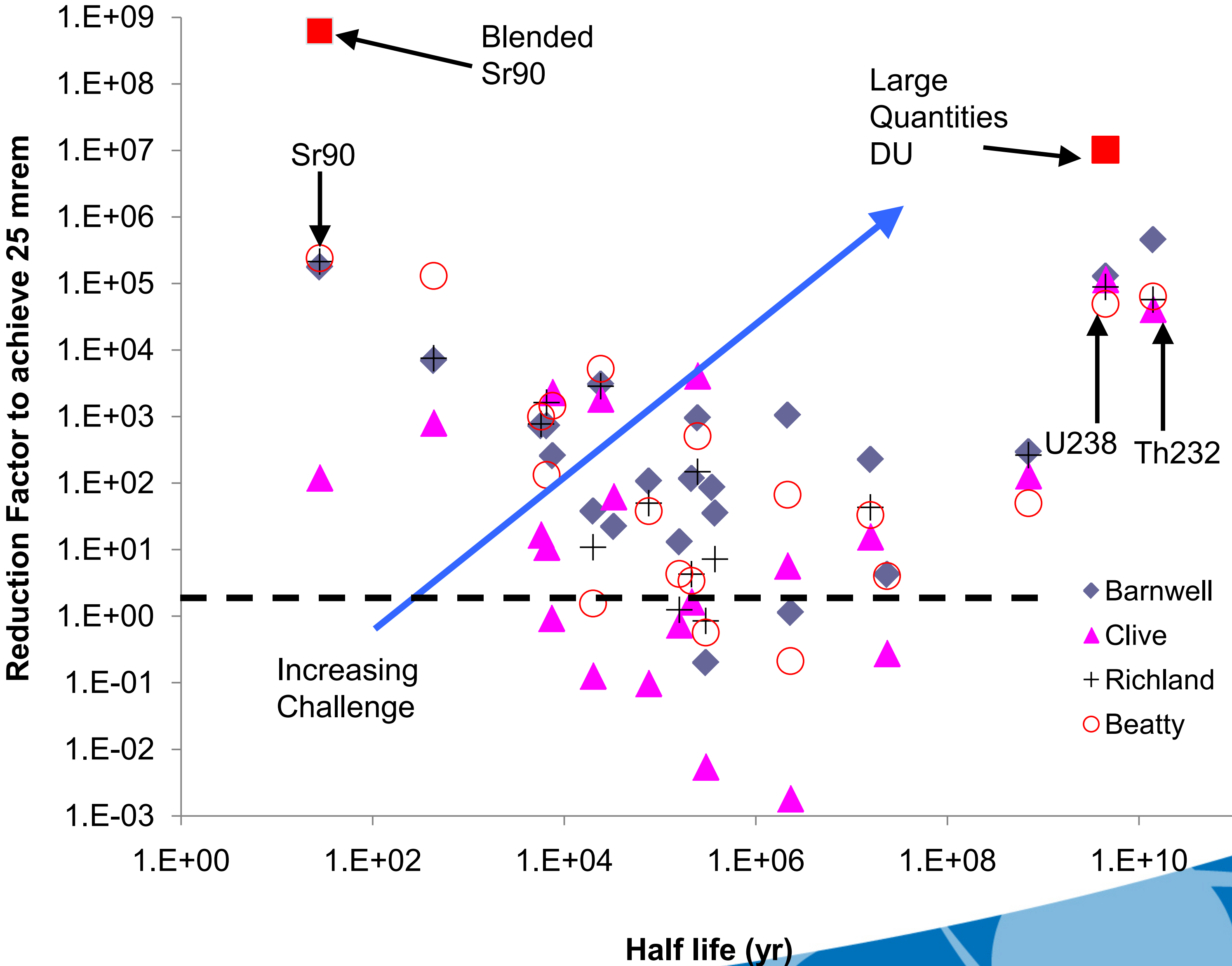
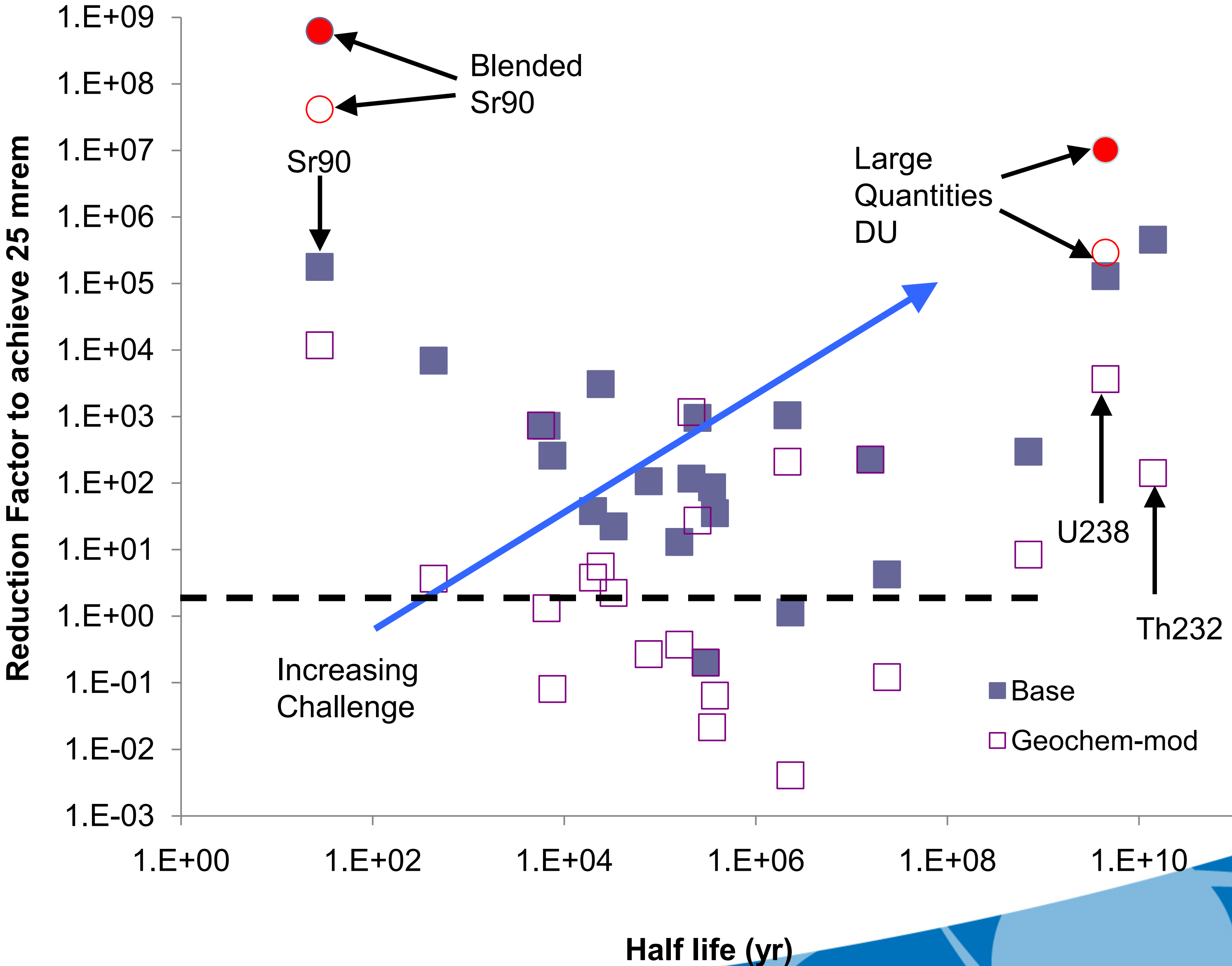
- Look at actual inventories disposed (use DOE MIMS database).
- Estimate the reduction factor needed to reduce the waste concentration to a groundwater concentration that would produce 25 mrem TEDE.
- Performance assessment is the process to verify that the necessary reductions will be achieved (sorption, solubility, dispersion, dilution).
- The next two slides are not PA results.

LLW Inventory Analysis



LLW Inventory Analysis



Uncertainty

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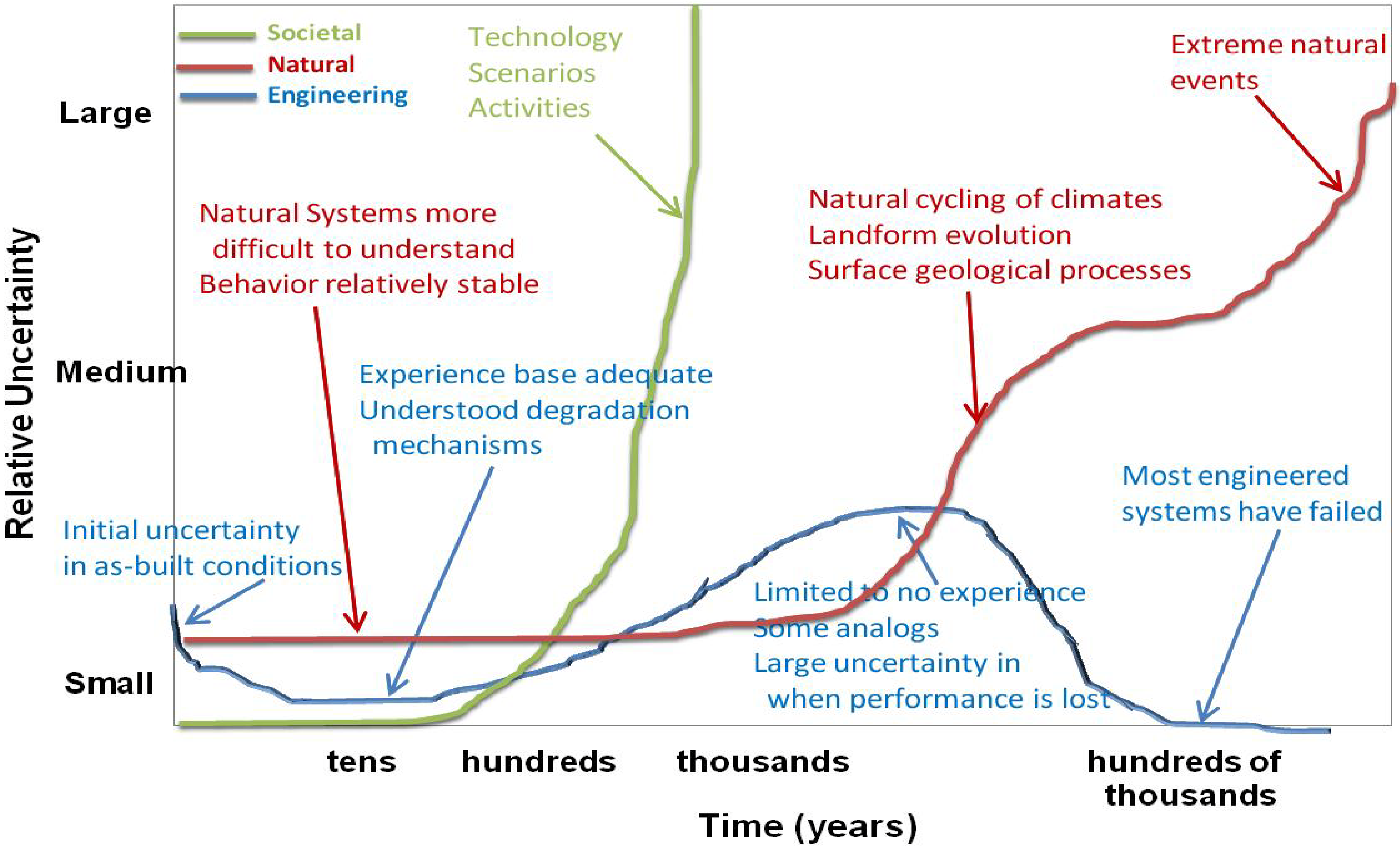

Options Considered

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1) No Change
2) Peak Dose
3) Regulatory Precedent (two tiers)
4) Uncertainty Informed Approach – three tiers, Compliance, Assessment, Performance (CAP)
5) Industrial Metals

Recommendation – Option #3

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Tier 1

- A compliance period of no less than 20,000 years, with a peak annual dose limit of 25 mrem TEDE.

Tier 2

- A requirement to perform a calculation of peak annual dose that occurs after 20,000 years as an indicator of long-term facility performance. No dose limit would apply to this analysis.
- A requirement to provide analyses that demonstrate how the facility was designed to mitigate long-term impacts.
- Associated changes to the regulations to highlight the uncertainties associated with disposing of long-lived waste and that limitations on the disposal of those materials may be needed to properly manage the uncertainties.

Basis for 20,000 years

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- Near-surface disposal is not geologic disposal – the stability issues are much more challenging.
- Natural cycling of climate is known/expected.
- A value of 10,000 years is more likely to be in the period of climate transition.
- Including climate cycling within the compliance period will encourage disposal of long-lived waste at more stable sites.

Basis for 20,000 years

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- While 20,000 years does not capture peak risk for all wastes, it captures more than shorter values. Possibly within 10x for depleted uranium.
- A value of 20,000 years better captures radionuclide transport characteristics (compared to 10,000 years).
- Diminishing returns for longer periods (affected by increasing uncertainty).

d(Radionuclide Transport) / d(Period of Performance)

Depth (Horizontal) / Climate (Vertical)	Shallow	Moderate	Deep
Arid	Se, Sn, Eu, Nb, Mn, Fe	U, Np, C, Sr, I	Tc, H, Cl U, Np, C, Sr, I,
Semi-arid	Pu, Ac, Co, Pa	Se, Sn, Eu, Nb, Mn, Fe	U, Np, C, Sr, I
Humid	Pu, Ac, Co, Pa, Zr, Th, Cs	Pu, Ac, Co, Pa	Se, Sn, Eu, Nb, Mn, Fe

[1] Ra, Pb, and Am were not influenced under any of the nine conditions

Sites with slow water flow

Sites with fast water flow

more mobile

less mobile

Basis for No Dose Limit for Second Tier

- Impacts can be better placed in proper context (NRC would complete environmental analysis of impacts for disposal licensing actions taking place in non-Agreement States).
- Approach better aligned with long-term decision making in other programs (e.g. disposal of industrial metals).
- Impacts better aligned with uncertainties.

Guidance on Period of Performance

- Risk-informed, performance-based guidance:
  - Would allow flexibility for short-lived waste or low concentrations of long-lived waste.
  - Would allow to go longer for high-concentrations of long-lived waste.

- Expectations for long-term analysis.

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Backup

Option #4 – Uncertainty Informed Approach (CAP)