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NUCLEAR REGULATORY COMMISSION

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597TH MEETING

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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THURSDAY

SEPTEMBER 6, 2012

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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., J. Sam Armijo, Chairman, presiding.

COMMITTEE MEMBERS:

J. SAM ARMIJO, Chairman

JOHN W. STETKAR, Vice Chairman

HAROLD B. RAY, Member-at-Large

DENNIS C. BLEY, Member

CHARLES H. BROWN, JR. Member

DANA A. POWERS, Member

JOY REMPE, Member

MICHAEL T. RYAN, Member

STEPHEN P. SCHULTZ, Member

WILLIAM J. SHACK, Member

JOHN D. SIEBER, Member

GORDON R. SKILLMAN, Member

NRC STAFF PRESENT:

DEREK WIDMAYER, DFO for Draft Reg Guide 1290 Discussion

CHRISTOPHER L. BROWN, DFO for ISG-8 Discussion

GIRIJA SHUKLA, DFO for US APWR DCD Discussion

DREW BARTO, NMSS/SFST

JEFFREY CIOCCO, NRO/DNRL

NATE JORDAN, NMSS/SFST

JOSEPH KANNEY, RES/DRA/ETB

TANIA MARTINEZ NAVEDO, NRR/DE/EEEB

EILEEN McKENNA, NRO

STEPHEN MONARQUE, NRO

MERAJ RAHIMI, NMSS/SFST

LARRY WHEELER, NRO/DSRA/BPTS

ALSO PRESENT:

JOHN CONLY, Luminant

JAMES CURRY, MNES

KEVIN LYNN, MNES

ALBERT MACHIELS, EPRI

MARCUS NICHOL, NEI

HIROKI NISHIO, MHI

HIDEKI TANAKA, MHI

DON WOODLAN, Luminant

T-A-B-L-E O-F C-O-N-T-E-N-T-S

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

(8:29 a.m.)

CHAIR ARMIJO: Good morning. The meeting will now come to order. This is the first day of the 597th meeting of the Advisory Committee on Reactor Safeguards. During today's meeting the Committee will consider the following.

First, Draft Regulatory Guide 1290, Proposed Revision to Regulatory Guide 1.59, Design Basis Floods for Nuclear Plants.

Two, Interim Staff Guidance 8, Revision 3, Burnup Credit in the Criticality Safety Analysis of PWR Spent Fuel in Transport and Storage Casks.

Three, Selected chapters of the Safety Evaluation Reports with open items associated with the U.S. Advanced Pressurized Water Reactor Design Certification and Comanche Peak Combined License Application.

Four, Assessment of the Quality of NRC Research Projects.

And Five, Preparation of ACRS Reports.

This meeting is being conducting in accordance with the provisions of the Federal Advisory Committee Act. Mr. Derek Widmayer is the designated federal official for the initial portion of this

meeting.

We have received no written comments or requests to make oral statements from the members of the public regarding today's sessions. There will be a phone bridge line. 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.

So at this point I'd like to turn over the meeting to John Stetkar who will lead us through the briefing.

MEMBER STETKAR: Thank you, Mr. Chairman. This morning we're going to hear about an update to Reg Guide 1.59, which is Design Basis Floods for Nuclear Power Plants. The draft, I think this is still true, has not yet been issued for public comments.

DR. KANNEY: That's correct.

MEMBER STETKAR: So we're getting an opportunity to give the staff some feedback prior to the Reg Guide being issued for public comments. We

felt that that was important for a couple of reasons. One is the current revision of this Regulatory Guide was issued in August of 1977 and a couple of errata, they're called, were added in 1980. But it's basically 30 plus years old, so it's one of the older one.

And because of the visibility of flooding, both in the context of licensing of new reactors and the response to the lessons learned from Fukushima, we felt that it was probably worthwhile for the Committee to take up --

MEMBER BLEY: Fort Calhoun.

MEMBER STETKAR: -- Fort Calhoun and other sites that have come to our attention, we felt that it was probably pertinent for the Committee to take a look at this earlier than we normally do.

So with that introduction I'll turn it over to Joe Kanney and we'll hear about what's up.

DR. KANNEY: Okay. Thank you, Dr. Stetkar. Thanks for inviting me to come in today and talk to you about Draft Guide 1290. At any point during the presentation if you have any questions please just stop me.

MEMBER POWERS: Don't provoke them, Joe.

DR. KANNEY: I've prepared a bunch of

slides so that we can talk about anything that you find interesting. You know, there's a lot of material but I just wanted to sort of be comprehensive so you have a good idea of what's in the guide. It doesn't mean that we need to go through each slide in detail, if it's something that you don't have any questions or don't want to have further discussions on.

Quick outline. After just a very brief outline, or background discussion, I'm going to go into sort of two main chunks of the presentation. One, I'm going to talk about several topics which are overarching and common to all the different flooding mechanisms that would just come up over and over again for each mechanism. So the idea is to sort of hit them at the top.

And then I'll talk about key aspects of individual flooding mechanisms and go through the flooding mechanisms that we touch on in the guide. Talk a little bit about combined events and give you a quick status on where the concurrence reviews are.

In terms of background I guess the most important thing to touch on immediately is why are we here, why do we want to update this guide? Dr. Stetkar mentioned the age of the guide and he correctly pointed out that it was issued in 1977.

There are a few errata over the several years after that.

There's one important piece that should be mentioned, that is shortly after the guide was issued the Appendix A, in the original guide, was taken out and replaced with an industry standard ANS-2.8 on Design Basis Flooding for Nuclear Power Plants. Now that particular standard has been updated since the late 70s, it was last updated in 1992. So that's maybe a little bit more fine-grained detail on the guidance.

But essentially we have a lot more data in terms of storms that have caused floods, actual floods at various types of facilities, dams, things that are of high hazard that have to withstand large floods similar to nuclear power plants. We have a lot of information that has been collected and analyzed in the intervening period since the guide was last revised.

In addition, a lot of this data is much higher resolution than was available at the time. You know, we didn't have digital elevation maps, LiDAR surveys were not common back in those days. So the combination of a lot more data and in some cases some very high resolution data. I didn't put it on here,

but things like radar observations of rain storms, things like that would fit into this rubric.

There have also been advances in the analytical methods and the tools. Higher dimensional and distributed hydrologic models. In terms of things like storm surge the models in use back in the late 70s didn't couple on the various physical processes that we know are very important to getting an accurate estimate of surge. Now we can do coupled multi-physics type surge models that put wind and wave together, for example.

And then there's also, these models can be driven by, and incorporated in, GIS systems so the entire modeling process, you know, a problem that was extremely hard or tedious or maybe even intractable in the late 70s is something that you could do on a desktop computer today.

And leading into that the computational resources have allowed us to just solve problems which were not very tractable in the past. So those are the main reasons the guide should be updated we think.

MEMBER RAY: What about the evolution of more quantitative ways of deciding what maximum credible means, for example. That has certainly evolved in seismology for example. Is that not a

reason to want to do the same thing here?

DR. KANNEY: I would have to say that in the area of hydrology and hydrometeorology, with the exception of some of the things that I mentioned previously in terms of the new data and the better models, the actual idea of how you postulate the very large rainstorm or the very large flood, those concepts really have not advanced very much.

You know, the idea of the probable maximum precipitation. The basic methodology that people use to come up with those estimates has actually been very static. The weather service in conjunction with some of the other federal agencies, like the Corps of Engineers and Bureau of Reclamation, worked on these methods during the 80s and during the 90s, but the methodology itself was remarkably static. Especially for the estimates for much of the Eastern U.S.

There were some developments on how you treat orographic uplift in areas of the Mountain West. But predominantly on the East Coast, where most of our plants are located, these methodologies have not changed very much.

CHAIR ARMIJO: Okay, well maybe I'll ask my question along the same lines. With the newest tools that you have, would the not only the magnitude

of the flooding around Fort Calhoun but the duration, would that have been predictable, or not necessarily predictable, but anticipated if one used the newest technology and tools on that site as far as flooding probability and the severity of the flooding?

DR. KANNEY: Well actually it's an interesting point that for the Missouri Basin, the Missouri Basin is so large that these probable maximum precipitation estimates didn't go up to, the estimates are basically --

CHAIR ARMIJO: Too low.

DR. KANNEY: -- the PMP you get a certain depth of precipitation over a certain area for a certain duration. That's how these estimates are put together. But the Missouri River Basin is so large that an estimate for basins that large actually was never developed at that time.

CHAIR ARMIJO: Can we do that now?

DR. KANNEY: You could. You could do it, but it was not done in these. What happened is there was a series of what are called hydrometeorological reports that were put out over the years and these have been, I'll talk about them later, but these have basically served as sort of the design documents for things like power plants, high-hazard dams, where

people go in, they have maps and for your particular location, then for the drainage basin that you're interested in. And the duration you're interested in and you can pick off what is the probable maximum precipitation. The largest depth of rainfall in that area in the time interval that's thought to be credible.

CHAIR ARMIJO: Yes, the last part of my question is should we analyze on a big area basis?

DR. KANNEY: We should be doing it for the area size that makes sense for the drainage basin we're interested in, certainly.

CHAIR ARMIJO: Okay.

MEMBER SHACK: I just want to make an interesting quote from one of your NUREGs. "There are readily available probabilistic alternatives to PMP for assessments and designs of critical infrastructure."

DR. KANNEY: Yes.

MEMBER SHACK: I thought you said before there wasn't?

DR. KANNEY: No, no, no. I said that the methods, you know, the probable maximum event type methods have been static. What's being referred to there is actually a probabilistic method, which is

not, you know, there's a really unfortunate --

MEMBER SHACK: That was the point of Dr. Ray's question.

DR. KANNEY: Yes, I mean there's a very unfortunate terminology that has crept into this particular discipline. The probable maximum event is it's a deterministic concept. Although the word probable is in there it is not developed from a probabilistic analysis, there is no return period or probability associated with it. It's very unfortunate terminology. I think it causes an awful lot of confusion.

But when someone talks about the probable maximum event, probable maximum flood, probable maximum precipitation in hydrology it's a deterministic number.

MEMBER RAY: Yes, well I appreciate that and I did have occasion to be deeply involved in that subject many years ago. And you're right, it hasn't changed until now. My real question has to deal with shouldn't it change and perhaps we should do something to try and make it change.

But let me go to something other than precipitation, because this flooding isn't just a result of a precipitation event, right? I was a

subcommittee chair not long ago for a COLA where the flood was driven by a landslide. So the issue of -- And of course we all know that seismic events can create a flood hazard.

So the real question then that I think Dr. Shack and I are trying to stimulate, and the Chairman as well, is you listed reasons to change the guide. None of which had to do with introducing or using or providing some incentive to develop applications in which this vague term of probable, as you say, undefined, what you mean by probable maximum and you get into great debates over that. But to make it more quantitatively determinable. Less deterministic, more probabilistic, okay?

And like I say although flooding is perhaps most commonly a result of precipitation, it's not the only reason. You can have dam failures, you can have tsunamis, you can have other things that we need to be concerned with. And so it just seems to me that that's a reason also to at least include in considering the update of this Reg Guide.

DR. KANNEY: As far back as 1992, ANS 2.8, last revision, in doing the probabilistic analysis it's not ruled out in the guide, it's been stated in our guidance that there are probabilistic methods that

can be used. The feeling, the judgement at that time, was that the methods were not, I don't want to say they weren't mature, but a widely accepted set of methodologies for the various flood producing mechanisms, or combinations of those, just wasn't readily at hand. So that providing guidance was probably an immature idea at that time.

It wasn't ruled out. The statement in the guide basically says they'll be looked at on a case-by-case basis. But that our guide was not going to provide specific guidance on the probabilistic methods themselves.

Now, the thing to remember is that even, this guide, the update that you're looking at now on all of the different deterministic models in terms of the higher resolution, some of the models that have better coupling between physical processes, you know, you can take these same models and with probabilistic treatment of key parameters you can do a probabilistic analysis using the same tools.

And none of this is ruled out. It's just that we felt it was more important to get an update out as quickly as possible, given the basis we have now. And in the meantime we are, you know, the research in conjunction with the New Reactor Office

and NRR we are actively looking at over the next several years putting together probabilistic guidance.

We're not there yet, but we didn't feel that it would be appropriate to hold all of this up while we did all of that, because everything that's here can be used.

MEMBER RAY: Okay, well.

MEMBER STETKAR: Gentlemen, let me ask you something. It's still related to this notion of probable maximum, but I'm going to try to stay away from real probabilistic analysis and think about it just in the context of the Regulatory Guide.

We had some discussion of this in the subcommittee meeting, but as I read through the Regulatory Guide the terms probable maximum, maximum credible and so forth appear in many different places. And yet it's, I think, very difficult, for me anyway, to understand what that concept really means.

In other words how does a regulator, or a member of the public for that matter, or a member of the industry, treat that concept. Because I see that concept presented in terms of the most severe hazards.

I see terms like, well they're the hazards that are the most severe that can be reasonably expected. I see terms that say, I've lost the quote

here, but essentially no risk of being exceeded. Those are very different concepts. The essentially no chance of ever being exceeded or the worst possible means that it can't be any worse than this.

What we're evaluating is something that is some physical limit to the severity or the consequences of a flood that can happen at a particular site. The water can't get any deeper than this.

In the other sense, it says can reasonably be expected to occur based on some evaluation of historical data. Well if that historical data goes back for a century it says well this might be what we expect to occur once in every 100 years or so. Or maybe once in every 1,000 years if we do some minor extrapolation.

What does that real sense mean in terms of a design-basis event. Is it something that we really expect cannot be any worse than that? Design-basis LOCA for example, is the rupture of the large, traditionally, has been the rupture of the largest pipe in the plant. I can understand what that largest pipe in the plant is, I don't have a bigger pipe.

Design-basis earthquake is something that's negotiated. It's something that has sort of a

frequency of on the order of once in every 10,000 to 100,000 years, depending on the site and specific parameters.

How does one interpret the flood that results from these design-basis calculations in terms of magnitude or frequency? Because I can't understand that just looking at the words in there.

DR. KANNEY: Well the magnitude is what you get by going through the analysis.

MEMBER STETKAR: I got that.

DR. KANNEY: It's interesting you say that, because there is actually, if you go to the World Meteorological Organization's manual on probable maximum precipitation it provides two definitions of the concept. And this is actually as far as I know, these two definitions were both developed by folks at the weather service.

One definition is what you quoted, the rainfall for a given area and duration that is thought to be the maximum physically possible. The other definition is it is a number provided by the meteorologists to satisfy the engineers.

MEMBER STETKAR: I'm glad you had that, because one of our members dredged up the exact quote.

MEMBER SHACK: It's in HMR-51.

DR. KANNEY: Yes, they quote it there as well.

MEMBER SHACK: That's the best definition I can find.

DR. KANNEY: It's I think a very accurate definition. Now, there is meteorological reasoning behind the probable maximum precipitation.

MEMBER SHACK: But I mean, couldn't you steal the sentence from HR-51 that qualifies that first definition that says, in consideration of our limited knowledge of the complicated processes and interrelationships in storms, PMP values are identified as estimates?

DR. KANNEY: Yes, they are estimates.

MEMBER SHACK: I know, but --

CHAIR ARMIJO: Throughout the rest of the document --

MEMBER SHACK: -- I don't see a sentence equivalent to that anywhere in the Reg Guide. You know, you get more definitions, like John quoted, it is the greatest possible. Well it is our wild-ass guess of what is the greatest possible.

MEMBER STETKAR: Well the reason I bring it up is because you are issuing this draft guide for public comments and it conceivably will be issued

sometime in probably the next year or so I would suspect. With the visibility of flooding, both domestically and because of Fukushima and the response to Fukushima.

I think that it's really, really important that the staff, in a regulatory guide that's published in 2013 let's say, pretty clearly identifies what is being calculated and what is not being calculated and how people should interpret that. Because I think otherwise it's too easy to misinterpret selected phrases in here and say, we've calculated the worst thing that could ever possibly happen.

Which is not true, and if something worse does happen it's not good for anybody.

DR. KANNEY: Point well taken. These are estimates. No one should ever be confused that these are estimates. All estimates depend upon exactly how you produce them. And estimates can be exceeded. There's one section in the guide where I talk specifically about that we have these design manuals, the HMRs, there are other, NWS-23 for probable maximum hurricane.

You know, these documents are compendiums of these estimates. They're produced at a certain point in time. And we point out that these things can

be exceeded. And the, let's say for example the HMRs, these are the ones we have today. There were ones in the past, for example HMR-51 the previous HMR for this region was HMR-33, and if you compare the estimates the estimates changed. And in some cases they went up.

MEMBER SHACK: But there's a bigger conceptual problem, because then you tell the guy, after he gets him PMP and PMF, that he's supposed to look at combined flooding things that sorted together have a frequency of 1×10^{-6}. Well what's the connection between that and the 1×10^{-6} if you really don't know what the probable is on the PMF?

MEMBER BLEY: That's right. They're estimates, but estimates of what? How do you interpret that?

MEMBER SHACK: And you're supposed to combine them with other events to get a 1×10^{-6} thing, and so you --

MEMBER SKILLMAN: Joe, I'd like to add a comment here. May I ask you to go back to Slide 3? You've identified the reasons to update this Reg Guide.

DR. KANNEY: Yes.

MEMBER SKILLMAN: And they basically deal

with, guess what, we have a lot of new data. We have a lot of new techniques. We've got some really neat computational capability. I think there's another piece of why to update the guide, and I believe we're touching on it here, at least one of us.

And that is because the way we use it has become more important. Based on what we witnessed at Fukushima, and a growing body of concern about waterways, dam failures, natural phenomenon that can inundate a plant.

I think what's missing is, why update this guide? Number one, there's new data. Number two, it's importance for use has been elevated. And there as some issues in how to deal with the type of thing Dr. Shack just mentioned. How you combine events. How you view terminology from historical, like the NOAA meteorological hydrological data. How you use those terms.

And it may be quite simple to add a paragraph or two or three that kind of puts that in context. So that the bulk of the update remains unchanged. But there's basically a description of the importance, given the new information that we have. But also a couple of how-to's.

When looking at the PMP, which is either

ACE, Army Corps of Engineers, or NOAA information, these are estimates. And when we use the word probability what we really mean is probability in terms of the plant's probabilistic risk assessment, not the legacy terms probable that comes from the legacy references.

It seems to me that that type of addition to why update the guide may address the types of issues that my colleagues and I are pointing to without undoing everything you've done.

MEMBER SCHULTZ: It also sets up the understanding of what needs to be done, as you indicated already. The plan is to issue this and then further develop other methodologies that really would lead us to be able to solve some of the problems that we've outlined just shortly.

But without, what's been suggested by Mr. Skillman, without that you don't set yourself up appropriately for the attention that needs to be placed on this guide as well as the follow-on work. So it would be helpful from that context.

DR. KANNEY: Okay.

MEMBER STETKAR: You asked us to ask questions.

CHAIR ARMIJO: You know this train is on

the track and it's going to hit us that the probabilistic flooding, probabilistic seismic, coming together to analyze things properly.

I just saw, Bill Shack sent me a Nucleonics Week, a recent one, in which in Japan now their experts in seismology are now predicting that at one particular site in Japan that the tsunami could reach as high as 34 meters above sea level.

This is at a site where they're building a sea wall 18 meters rising above sea level. It seems that those are bizarre numbers to me, but these are expert seismologists. And pretty soon people are going to be asking us in the United States, are we off track. Do we know how to do this kind of work? Are they doing it right? Shouldn't we be doing it the same way? And we're just saying hey, we've improved our deterministic methods to make estimates.

That may be fine. I don't know, I'm not a PRA person, but it's the same data and how do you use that same data in a way that's a more modern way to, so you can do things like combine the effects of probabilistic seismic with probabilistic flooding.

It seems like we're behind the curve as far as the methods that we use for this work. I don't know how to do this myself. Somebody must know how to

do that.

DR. KANNEY: I think it's a fair statement that in this area of hydrology with respect to the extremes. Now if we were talking about something, of floods of much lower magnitude, say the 100-year flood, ten-year flood, 20-year flood. You know, things that are of interest to designing culverts for highways, bridges and things like that, probabilistic methods are used quite routinely.

It's when we get out to these very large, very extreme events that a sort of widely accepted, very well widely applied set of methods that, okay, we all do it this way, we all understand it. That's lacking when you get to the extremes.

And traditionally the way of handling these extremes has been this probable maximum event type concept. You look at the historical information that you have. You look for the most intense storm or the largest flood that you've seen in the historical record.

Now the historical record can include paleo records. I think that's a lesson that has probably been learned in the last couple decades, how valuable that kind of information is. When the guide was last revised that whole field of paleohydrology

was just in its infancy.

MEMBER SIEBER: To what extent are the real far back records really considered? For example, my house is in a valley and if you look up on the hillside you can 17 shorelines due to ice-age effects. And the very top one is about 500 feet above the valley floor, which is difficult for me to imagine that that would occur in modern times.

On the other hand the evidence is there that there was this huge flood that went all the way up into Canada. And so if you find geologic evidence that massive floods can occur to what extent does that extend to construction of a facility that will have a lifetime of 60 years in a more moderate and temperate climate?

DR. KANNEY: Well you wouldn't necessarily apply that knowledge to today if you thought the climate was different. The major use of the peleohydrologic studies is to put into what are called flood frequency analysis. Okay?

That's basically having information on these paleo floods allows you to put in not necessarily a data point, but an interval. You know that in a certain timeframe you either did not see a flood of a certain magnitude or you saw a flood of at

least a certain magnitude in a certain time interval.

And there are methodologies for including that information into a flood frequency analysis to get average annual exceedances to get put that information in. But all of those methods are based upon the idea that there is stantionarity in the process.

So if you had reason to believe that that very large flood you saw was in a different climatic regime, you wouldn't put that into a flood frequency analysis that you think represents the current climatic regime.

But if you think that it falls within the current climatic regime, say the last 10,000 years or so, then certainly you would put it in.

MEMBER SIEBER: Well one of these shorelines is 17,000 years and it wasn't just the flood it was the fact that it got an ice dam that blocked it. And those kinds of things can happen more frequently than the large-scale climate change that occurs over a period of 100,000 years or so.

You know, it's unique and it's local, but it's severe. So to me it's difficult when you look at probabilities and decide at what level you're going to build something. That probability never goes to zero.

DR. KANNEY: Right.

MEMBER STETKAR: So in the interest of time, I think we've had a pretty good exchange about probable maximums and PRA and things like that. But there's a lot of material in this draft guide and I think it would be really useful to try to get through basically its treatment of the different flood causing mechanisms and combined events, if we can do that.

DR. KANNEY: All right. I'll spin through this first part fairly quickly. There's several topics which are common to most of the flooding mechanisms that are addressed in the guide. One obviously is you have to have certain criteria and pieces of the site hydrologic description.

And the guide goes through for various settings, you know, riverine settings, coastal settings, what sorts of things you need to include in the hydrologic description of your site. We also point to data sources for this type of information and things of that nature.

One thing that sort is overarching, we've touched on this, and that is in the past designers have used what I called these design documents. You know, the hydrometeorological reports, the probable maximum hurricane wind field reports, in order to

develop these estimates for the maximum credible floods.

And all of these documents that are out there are quite dated. There's more recent storms that have happened since these documents have been developed. It doesn't say that these documents are useless. It really depends upon where you are.

And so what we've put into the guide is bottom-line is there's due diligence required if you're going to use these types of documents. You need to ascertain whether, for the particular region you're interested in, whether the assumptions or the data that these reports are based upon is still valid. Or whether you need to go in and redevelop some of these basic ideas.

We've touched a little bit on non-stationarity. There's several non-stationary aspects with regard to flooding. The ones that we address in the guide, because we think they're tractable to address, are things like sea level rise and certain climate change impacts. Basically how climate change may impact sea level rise and how that may factor into estimates of coastal flooding.

For other aspects, in terms of increases in storm intensity, increases in precipitation,

increases in stream discharge, we look through what is available in terms of the climate modeling that's done and compare that to what people have been observing. And it's really a very confused stated of affairs right now.

You know, if you look at different climate models some of the climate models don't even agree on the sign of the change in some of these processes once you get down to a specific location. If you're talking about global averages there's a lot of consistency.

But you don't build a plant or a dam using global averages. You've got a site and you need information about the site and the surrounding region. When you get down to that scale there's really not a lot of good information that you could extract from say climate models and plug into a hydrology model and thing that you have reduced uncertainties. I mean you can do that process, but we don't think that you've actually reduced the uncertainties in your estimate by doing that.

I think we've hit deterministic versus probabilistic well enough.

Okay so let's shift into, I'll quickly go through the individual flooding mechanisms that we

cover in the guide. Okay, local intense precipitation. What we're talking about here is a very intense rainstorm that happens right at the plant site. Regardless of where the plant is located with respect to the normal water level of the ocean or the river or wherever. The plant can be on top of a mountain and you still would have to worry about this flooding method.

It's basically this is the analysis you go through to ensure to yourself that the way that the plant is graded and that the drainage system that has been designed can handle this local intense precipitation. And that needs to be done at each site.

The other, and this basically in theory this could be the only thing you have to do. In theory. But this is one that you could never argue that it's not applicable. All of the other mechanisms individually might not be applicable to a site. And by looking at the data and simplified engineering analysis of a particular region one could make the case that no, this particular mechanism is not applicable.

Riverine flooding is, as you well know, many plants are located very on or near rivers. So

riverine flooding is a mechanism that really needs to be examined for many, many plants. And the traditional way that this has been looked at is to look at the most extreme flood that's considered credible.

Typically you have a river basin and you apply your estimate for the probable maximum precipitation to that river basin. You estimate the runoff that's going to hit the stream or river from that rainfall. You route that discharge down to the plant site using very conservative assumptions along the way. For example, in the rainfall runoff you cold assume that there's basically no losses.

You know, that the ground acts like a rubber sheet. All of that water that falls in the basin gets to the stream and you route that down. That would be one example of how these probable maximum flooding estimates are some derived, by applying those types of conservatisms with a rainfall that you think is the largest credible, or your estimate.

Now also with riverine flooding one has to look at several different mechanisms which may combine. It's not just the rainfall necessarily. In some regions you have melting of snow pack combined

with rainfall. I guess the most recent poster child for that would be the Fort Calhoun, the flooding on the Missouri River in 2011. That was a combination of much higher than normal snow pack combined with very large and long duration storms.

And so the timing and the sequencing of snow fall, snow melt with storms need to be looked at, if that's a credible mechanism for the region you're in. Also rainfall and the extreme discharge might be the cause for dam failure on a particular river. So combinations where you have a dam failure caused by a hydrologic event, like very large flows. Things like that need to be considered in riverine flooding.

Also it may not be immediately obvious to everyone. But also wind waves are typically superimposed upon the flooding that you calculate. You know, the discharge in the stream that you calculate. For the simple reason that many large storms are accompanied by very large winds. And you can have wind waves on the body of water that may add to the water level.

I guess I probably should have started with this slide first. The key pieces of the riverine flooding. You know you're going to have a design rainfall, you're going to apply it to your basin.

You'll do some sort of rainfall runoff analysis. That gives you your effective precipitation, what actually gets to the stream channel. And then that would be routed to the site.

Now in all these cases there are models which you will apply. For the flood routing we say that you should look at whether 1D or 2D models are appropriate. In the past 1D models were typically used for this type of analysis. I think the conventional wisdom is a 1D would be more conservative. Once you start populating a river basin with more detail in a 2D model sometimes you find out that the 1D is not necessarily the most conservative.

So that we suggest that you should look at whether 2D models are appropriate, they sometimes can be. And typically what we advise in the guide is that dynamic flood routing should be used unless one can show that the water level profiles are shallow enough that a steady state analysis might work.

I guess a good example would be say if you were in a area with very high relief in a relatively steep drainage basin versus the Mississippi River. Basically is the storm producing a flood wave or is it a much more gradual increase in the hydro graph. In the latter case you might be able to use s steady

state analysis. In the former case you would not.

CHAIR ARMIJO: I had a question. To what extent are the actions of, let's say the Corps of Engineers, in deciding to open floodgates? In other words create a situation that you hadn't analyzed? In order to protect a certain area they just basically flood another. Is that built into this deterministic analysis? Because it depends on what they decide to do, so how are you going to analyze for that?

DR. KANNEY: You know the assumptions that you put into this model have to reasonable based upon how, if there's a reservoir upstream, you do need to understand how this reservoir is going to be operated. However, you can't take credit for it. To say we always know say, for example, the Corps has a dam upstream, we always know what they will do.

CHAIR ARMIJO: I don't think so.

DR. KANNEY: We don't. We don't always know what they will do.

CHAIR ARMIJO: Okay so you deal with that and they have to assume that they may do something harmful to the plant as far as flooding?

DR. KANNEY: That eventuality has to be considered. Because what can, my understanding is that what does happen in practice is that there may be

a memorandum of understanding. Some durable agreement between an upstream dam owner to give notice of what they're going to do. But that's about as far as it goes. That's my understanding.

MEMBER SIEBER: In the case of Fort Calhoun it was downstream dams that limited the height of the water at the plant, because they did open those up but I don't know that they opened them up to protect that power plant or just all of the upstream residents and I don't think I want to know.

MEMBER STETKAR: This is an interesting topic. It isn't quite germane I don't think to this particular Reg Guide, but we did have a little discussion of it. And it's analogous to guidance that the NRC has in place for communications between a nuclear power plant owner/operator and electrical grid operators. There's guidance in place that says there shall be those lines of communication both ways so that people know how to manage loads.

To my knowledge there's no such guidance in place for managers of riverine systems, dam systems, and owners/operators of nuclear power plants. There may be ad hoc local agreements or memoranda of understanding.

But to my knowledge I haven't been able to

find any NRC guidance that says if you're on a large river system, Mississippi, Tennessee Valley or something like that, that you as a nuclear power plant operator need to have some formal lines of communications with the people who operate those dams so that you know how they're going to manage a particular flooding even or other types of things that happen.

As I said, it's not germane particularly to this Reg Guide because it's not sort of design-basis flooding. But it does address, Sam, your concern. And I think it is, it's sort of, you know, I don't look at managing a river any different than I look at managing an interconnected electrical grid.

MEMBER SIEBER: Well I think you're right in your characterization of that. There are ad hoc agreements and in my experience we use them. But there is no formal mechanism between power plants or the system operator and the Corps of Engineers, for example.

DR. KANNEY: I'm not aware of anything either.

MEMBER STETKAR: We've asked a couple times in different venues and have received sort of the same feedback, that nobody seems to be aware of

any formal mechanism or requirements. Dam failures.

DR. KANNEY: Okay. One of the other flooding mechanisms for power plants located in river basins is potential dam failures. And when the guide talks about dam failure we'll make it very clear we're talking about basically anything that's going to store water. Obviously dams upstream of the site.

But there could be dams downstream whose failure could cause backwater effects that might effect your plant. There could be other water control or water storage structures. Auxiliary reservoirs, cooling ponds, levees, things like that. And we make it very clear in the guide that all of these are included, it's not just what the common concept of a dam is.

MEMBER STETKAR: Before you get to the second major bullet there.

DR. KANNEY: Yes.

MEMBER STETKAR: We did have some discussion, you mentioned downstream dams in terms of backwater effects for inundation flooding at a particular site. We had some discussion in the subcommittee about the effects of flood-causing mechanisms, precipitation or seismic events or something like that, that effect the whole water

system and remove a downstream dam or other water control structure that serves as an impoundment for the plant's safety related cooling water supply.

So that, for example, you could have a flood that perhaps by itself results in fairly modest inundation levels at the site. But in combination with that takes out the downstream dam and you've lost your safety related cooling water supply. Right now the guidance, as I understand it, does not address those types of failures, is that correct?

DR. KANNEY: The guide talks about the systems and structures and components that need to be designed to withstand floods. And those are the same components that are identified as in Reg Guide 1.29 as needing to be designed to withstand seismic events. My understanding is that say the downstream dam that provides the water for your ultimate heat sink would be included in that.

CHAIR ARMIJO: The vulnerability of that?

DR. KANNEY: It would be a --

MEMBER STETKAR: It doesn't seem clear from, I mean that certainly doesn't seem clear, at least from my reading of the Reg Guide. In principle I guess that's true. But it seems to focus on inundation flooding of structures, systems and

components on the site grade because it talks an awful lot, everything is related to upstream and elevations higher than site grade.

And I'm just curious whether somebody applying this guidance would not recognize the need to examine the effects of simultaneous, coincident, dependent, whatever you want to call it, mechanisms that could also effect that downstream, I call it downstream, but a water impoundment structure that holds the safety related cooling water supply.

MEMBER BROWN: Didn't you ask this question once before on, was it Watts Bar or another project?

MEMBER STETKAR: I've asked it two or three times. Yes, you're --

MEMBER BROWN: On a downstream dam, and I thought the answer that came back was that they hadn't looked at that. That's a bad memory maybe, but I --

MEMBER STETKAR: No, that's --

MEMBER BROWN: -- remember we've talked about it in regard to at least one or two projects.

MEMBER STETKAR: That's an excellent memory. That's a precisely correct memory.

MEMBER BROWN: It's better than I thought it was.

MEMBER STETKAR: That's one of the reasons it prompted my questions. We had spoken on a particular licensing issue on this. And the answer was no we haven't looked at that. The response at that time was, well that's not a source of flooding.

MEMBER BROWN: Exactly.

MEMBER SCHULTZ: Here it's addressed in many indirect ways, but not directly.

DR. KANNEY: You're suggestion is it needs to be clarified?

CHAIR ARMIJO: Maybe a few words to make that clear.

MEMBER STETKAR: In the, I've forgotten which Appendix it is, but in the appendix on dams, indeed it says to characterize the site you have to describe dams that impound the site safety related water supply. But then immediately it talks about everything in your first bullet there, which is basically upstream flood waters invading the plant site, plant grade basically.

DR. KANNEY: Okay, point well taken.

MEMBER SHACK: Even in the Fukushima Phase I analysis of the flooding hazard, you know, that's a debate that goes on as to whether --

MEMBER STETKAR: There is another place

for example the question has been asked. The last Commission meeting was full of that.

MEMBER SCHULTZ: There's a lot of discussion and attention paid to debris that can effect the ultimate heat sink. But this very direct impact is not described with the clarity we think it needs to be.

DR. KANNEY: The last bullet here then just mentions that some dams might be screened out. I mean because if you go to a lot of river basins, it may be not widely recognized among the public, but you can go to large river basins there are hundreds of dams. Many of them are quite small, they impound very little water. They have low differential head. They're very far from the plant.

And one can go through a fairly simplified analysis to screen those out and get down to the larger dams, the ones that do have an ability to impact the plant. And those are the ones that really should be, the impact of their failure are the ones that really need to be analyzed. That's really what this bullet is trying to take into account.

There are different modes or categories of what I call predominant mode of failure for dams. Because quite often it's not really clear why some

dams fail. And there may be several mechanisms that contribute to a failure. I mean as engineers and scientists we always like to kind of categorize and chunk things, but in the guide we sort of point out that --

CHAIR ARMIJO: I had to ask. What's a sunny-day failure?

MEMBER STETKAR: That's exactly what he's talking about.

CHAIR ARMIJO: Just you don't know why it failed but it did fail?

DR. KANNEY: Well for the classic example of a sunny-day failure is say for example you have an earthen dam. And I guess the thing to make sure everybody's aware of, dams don't stop water. Dams slow water down. There is flow of water through dams, okay? A good dam is designed such that the water flows through the dam in such a way that it doesn't impact the structural integrity of the dam.

However, things like piping where, due to internal erosion, you basically create a pipe that water goes though. Once that preferential flow path has been established then you get more erosion. And that starts to eat away. And then you literally get a pipe and you can fail an earthen dam or a rock fill

dam in that way. That would be a classic example of a sunny-day failure.

And really it's pretty much it's things that are hydrologic, not related to a flood either overtopping some portion of the dam or being too large for the spillway, dam spillway to handle. And not due to a seismic failure. They get the name sunny-day failure because they can happen at any time.

If you look through the history of dam failures you will find that these sunny-day failures, a good portion of them, happen very early in the life of the dam. Some on first filling. But they can happen anytime.

MEMBER BLEY: I'm just curious. Over the years have folks come up with ways to monitor for the developing pathways?

DR. KANNEY: Yes, there are a variety of ways that you can monitor a dam such that you at least have some forewarning that there is some structural problem with the dam. Some of them are very simple and very crude, you go out and walk the dam face and you look for places where the grass or vegetation is well watered, growing really well. It's an indication that there may be some excessive seepage in that area. Or you look for water seeping through itself.

You can install piezometers in the embankment and monitor those. You can use geophysical techniques. You can actually do things like electrical resistivity surveys.

MEMBER BLEY: But do we, or does the Corps of Engineer have requirements for this sort of thing?

DR. KANNEY: Well the dams are regulated by a variety of entities. The Corps owns and regulates their own dams. The Bureau of Reclamation owns and regulates their own dams. A few of the Bureau of Reclamations dams are actually operated by local irrigation districts. They would be the people that would probably be implementing a Bureau of Reclamation established program. In a lot of cases with the smaller dams they're regulated by the states.

MEMBER BLEY: I guess what I was getting at is if we have a plant for which such a failure would be a crucial problem do we have any way to make sure it's being monitored? Such that the likelihood of its failure isn't getting worse year-by-year?

DR. KANNEY: The answer is yes, but it's not a uniform regulatory framework. In some cases there will be a federal entity. The Federal Energy Regulatory Commission, FERC, has regulations for dams owned by utilities that are producing power. So

there's several different federal agencies. A lot of dams are regulated at the state level.

In general there are requirements for monitoring and inspection. Typically on the order of annual inspection for most dams. But it is a patchwork.

MEMBER STETKAR: I don't think we have anybody from NRR here, I'm not sure. We've had some discussion about this. I know the Agency does have, and I've forgotten the name of the --

DR. KANNEY: Oh, we have a Dam Safety Officer.

MEMBER STETKAR: Thank you. That the Agency does, I believe, coordinate at that level with these various and sundry regulatory groups.

DR. KANNEY: My understanding is at the federal level where we coordinate, there is a federal dam safety body and I believe it's the director of FEMA is actually the titular head of that body. But we have a representative on that body as well as the Corps, the Bureau of Reclamation and other federal agencies. To my knowledge we don't do a similar level of coordination with states on a routine basis. I'm not aware of it if we do.

This slide was just meant to cover the

idea that in the guide we talk about different modes of dam failure. And that the different modes needs to be addressed.

Unless, as a practical matter, what often happens for design-basis calculations the easier things to do, in terms of analysis, is you just assume the dam vaporizes. It goes away. And if that severe of an incident doesn't impact the plant well, you're done.

If that's not the case then more in-depth modeling of credible failure modes and the resulting flood wave needs to be addressed. But in many cases it's much simpler just to assume the dam fails and route the flood wave to the plant and see whether that has an impact. Whether that winds up being a design flood or not.

And then in all cases in dam failure, as with the riverine flooding, sediment transport and debris flows need to be taken into account.

Coastal flooding --

MEMBER SKILLMAN: Can we go back for a second?

DR. KANNEY: Sure.

MEMBER SKILLMAN: On dam failure, one of the things I've witnessed when really over top in

river, there's such a huge flow, particularly in spring runoff in a narrow channel like the Allegheny River, which is what I'm particularly familiar with, is the debris transport, but it's just not logs and sticks and that kinds of things. It's boats and automobiles and houses. Travel trailers, upside down tanks, septic tanks that have come out of the ground. Portions of graveyards that have come out of the ground.

So when one talks about sediment and debris I just wonder what caution you have in the Reg Guide for stunning quantities and stunning sizes. I've seen it happen.

MEMBER SIEBER: You're thinking of the Johnstown flood.

MEMBER SKILLMAN: I'm talking railroad cars, empty railroad cars. Or railroad cars that are filled with wood. Things like that, that are maritime missiles is what they are.

DR. KANNEY: For wind generated missiles we have a very stylized way that we actually postulate various sizes and types of missiles. We don't do that in the flooding arena. But your point is well taken and I think it's well understood that debris is not just trees and logs. You know in order to make some

assessment of what sort of debris would be credible you would need to look at the river basin itself. What's in that flood plane, you know what can be there.

MEMBER SKILLMAN: Does the Reg Guide communicate that?

DR. KANNEY: The fact that you asked the question means that it may not communicate that as well as it could.

MEMBER SKILLMAN: Thank you. I made my point.

DR. KANNEY: I mean the Reg Guide itself really just talks about debris and doesn't get into the --

MEMBER SKILLMAN: I just think and exclamation point. The type of debris can be larger and more dangerous than one might have considered. For example, it could be propane tanks. They're buoyant and they're mighty dangerous.

DR. KANNEY: Yes, it's not really that well recognized that one of the things that happens in a lot of floods is there are fires due to the natural gas and propane infrastructure.

MEMBER BLEY: Fukushima, there was fires all over.

MEMBER SKILLMAN: Thank you.

DR. KANNEY: Thank you. Okay. Moving on to coastal flooding. We point out in the guide, we sort of define what we mean by coast. Again, because a lot of people may think coast, oh that means your near the ocean. Coastal, we take it to a very broad definition in the guide so it's clear that we're not just talking about ocean side regions.

And there are a variety of mechanisms that can happen in the coastal regions. Obviously storm surges, seiche, tsunami and along with wind waves due to storms themselves. All of these things need to be taken into account. Or possibly may need to be taken into account in the coastal regions.

And then with any of these mechanisms the interplay between the astronomic tides needs to be taken into account. And in the case of storms we also have the attendant wave setup and runoff mechanisms that need to be considered when looking at these sorts of mechanisms.

Storm surge. There are different types of storms that will generate surge in particular regions. I think, when people talk about storm surge we typically think about hurricanes. But depending upon, you know, the hurricanes only strike a fairly limited

area of the coast. There are other areas of the coast where extra-tropical cyclones, including hurricanes that have transitioned. You know, the post-tropical storm portion of a hurricane. Essentially they can transition into extra-tropical cyclones.

And then even in inland bodies, such as lakes, you can have squall lines. I think the derecho that moved from the Midwest all the way to this region of the country really focused people's attention on the wind speeds that can be generated by these types of storms. And the squall line that I have there, that's another name for the derecho in the meteorological literature.

Once thing I wanted to mention here is that in the old Reg Guide, the previous revision of the Reg Guide, there are maps that are proposed for use as screening. To screen out whether, or to get sort of a rough conservative estimate what a storm surge might be along the coast of the U.S. And we're specifically saying in this guide you shouldn't be using those maps.

For several reasons. One, as with the older design documents we talked about before, the information, the data, the storms that it was all based upon are 30 to 40 years old. We've seen more

recent storms. The analysis was done using very, very crude storm surge models that were available at the time.

And we point out that recent work that was sponsored by NRC has proposed an updated screening method that realized much more on, tries to account for uncertainties in the mechanism as well as using updated models. I don't think we have time to go into that screening method itself now, unless you want to.

But unless you can clearly rule out that storm surge might affect the site, then a detailed analysis needs to be done. And that detailed analysis should include, obviously, a detailed analysis of any historical storm events that occurred in the region.

This is very critical because even though we have these more modern models for predicting surge, you know, that couple various physical mechanism like the winds, the waves and account for the near-shore bathymetry and topography that the surge is going over, these models still have to be essentially calibrated and validated and using historical, detailed evaluation of historical events in the region are the still the best way to do that.

And we sort of lay out what we feel is the current state-of-the-art in storm surge model. And

that is to use a coupled hydrodynamic ocean circulation and wave model and drive those models with a wind field either from, I call it here planetary layer model in the case of the hurricane that would be your hurricane wind field. In the case of an extra-tropical cyclone it would still be planetary boundary layer model but it wouldn't be that very classical hurricane vortex type model.

The models are still coming from the same sorts of numerical weather forecasting type tools. But the model is not as simple as a hurricane vortex. And we have available to us very high resolution bathymetric and topographic data that needs to be put into these models, because the near-shore bathymetry can have a dramatic impact on the surge that you actually see at a specific location.

And this, in terms of the digital elevation maps are available, things like LiDAR, you can really get a good handle on this sort of information these days.

Seiche, there's not really much new in the Reg Guide with regard to seiche. Basically seiche is the phenomenon where you basically have some forcing from a variety of mechanisms that is close enough to the resonate frequency of a enclosed or semi enclosed

body of water that you set up this sloshing action.

And depending on where you are and the shape of the water body of interest, say for example if you're on a nice, you know, the cooling pond is the body of water you're interested in, and it's got a nice regular geometry, that there's some simple formulas for calculating the modes of excitation for bodies like that.

For more complicated bodies of water with very complex boundaries or bathymetry you'd have to go to more complex hydrodynamic models to figure that out. We also stress that you need to really consider what the forcing functions could be for your particular area. And they could be local or regional, you know, things like a storm coming in, the derecho phenomenon for example.

Strong winds are very, you know, on the Great Lakes in particular the seiche that's set up by storms over the Great Lakes is a very well known phenomenon as you get very dramatic changes in water level where the storm is coming in and the winds are blowing and then all of a sudden they change direction or it stalls and all that water comes back the other way.

So you can get flooding where the water is

being piled up on one side but when the wind changes direction the water level can go back the other way in a hurry.

MEMBER STETKAR: I don't want to interrupt you, but we have a few more slides to get through and we have about 12 minutes. And there are a couple of topics I think we may have a little bit of a discussion on.

DR. KANNEY: Okay. Tsunami. For the tsunami this is based on a NUREG that PNNL did for the Office of New Reactors in 2009. And they went out and looked at the current research on tsunami and laid out a methodology for looking at tsunami for nuclear plants, in terms of identifying the hazard zones like the coastal inland sites, laying out the different effects that one would need to look at for tsunami, both the runoff and the rundown and proposed a screening method that looks for possible tsunamigenic sources in the region.

And if it couldn't be ruled out that there were none then basically some sort of postulated or hypothetical source would have to be developed and then the impact of the tsunami from that source model.

Ice effects. Here again you can look at data for the region to see whether ice jam formation

is a potential hazard. There are several areas to look at for data in terms of just the weather data NOAA collect all this information. And there's also an ice jam database on actual ice jam formation that's maintained by the Army Corps of Engineers and these would sort of be your first source to decide whether or not there's potential for ice jam formation in the region that you're looking at.

Once you've decided that there is that potential again you're in the situation where you sort of have to postulate that one forms, you know, look at upstream/downstream effects of a dam forming and through backwater effects flooding your site. Or a ice dam upstream that then fails and there is a flood wave coming towards your site from it.

But these things basically there's no methodology for predicting exactly where an ice jam is going to form and what shape and how big it might get. You know, you really have to postulate something.

MEMBER SKILLMAN: Have you considered ice effects from the perspective of the ice itself as a mechanical projectile? I'll give you three examples, on the Ohio at Beaver Valley. The Prairie Island on the Mississippi. TMI on the Susquehanna.

When the ice begins to break up there can

be chunks of ice that are big as this building, four feet thick. And they're moving. And if they move in the wrong geometry they can getting into the circ water pump valves or into the raw water intake, or the essential raw water intake portion.

They are in fact part of the flood, they're a flood of solid water. And their mass is immense. And so while it is flooding it's not flooding but it is certainly a water-borne element that poses a very large potential risk.

DR. KANNEY: Yes, there is, it's not on this slide but there is a section in the guide where we discuss it. The forces due to the ice need to be considered as well. Not just, you know, in terms of ice effects, one of the ice effects that's listed there is the impact of the ice force.

MEMBER SKILLMAN: Thank you.

DR. KANNEY: Combined events. I think it's well understood by most hydrologists that, if you're trying to postulate a very large flooding event, you need to consider combined events. In our common experience on certain river basins, say for example on the Missouri recently where you have a combination of snow melt and large storms, it's well known that that combination is something you should

look at.

But on other river basins, and other combinations of mechanisms need to be considered as well. It's true that when you're looking at hydrometeorological events they don't necessarily occur independently. Large rainstorms have high winds, so these effects need to be considered in combination.

And then there are also some combinations you want to look at just because it's possible that things may coincide. For example, you have a storm surge, it may or may not coincide with high tide but you certainly better analyze the fact that it could occur at high tide.

So in some cases the events are considered independent you're looking at this sort of qualitative, probabilistic assessment of putting some things together. In other cases there are events which you ought to consider that happen together. So both variety of combined events here.

And the 10^{-6} average annual exceedance as a target or a goal is something that was first, to my knowledge, first proposed in the ANS-2.8, which is Appendix A of the Guide. And it's proposed as a target, as a goal. Something that the folks that put

that standard together considered reasonable.

MEMBER STETKAR: Joe, in the interest of time, I have to be really careful here, but to bring up something that the other members who weren't at the subcommittee meeting didn't hear. Appendix H of the Reg Guide includes guidance on the treatment of combined events. And there's a laundry list of what I'll call stylized scenarios and we had some discussion about that.

And I'll just read the first one to give the rest of the members some of the concern. "Alternative 1 from precipitation is mean monthly base flow with median soil moisture and antecedent or subsequent rain, the lesser of one rainfall equal to 40 percent of probable maximum precipitation or a 500 year rainfall. The probable maximum precipitation and waves induced by two-year wind speed applied along the critical direction."

It seems that those are very stylized and prescriptive. And despite the caution to not use them as a cookbook, I fear they will be used as a cookbook. And people will somehow infer that they some relationship to this 10^{-6}, which is not at all clear to me. We had some discussion about this that perhaps they ought not to be so prescriptive.

1 That's not just a single example, there
2 are 19 of them for example. And they kind of read
3 like a cookbook. If you do all of these then indeed
4 you're good. And reviewers who will look will force
5 you to look at all 19 of those and nothing else.
6 And I think there's a danger there that
7 you might be forced as an applicant to look at
8 something that is irrelevant for the site and justify
9 why it's irrelevant. And not look at something that
10 indeed that might far exceed this 10^{-6} goal. So you
11 may want to think about softening the kind of
12 prescriptiveness of that list.
13 DR. KANNEY: Yes, as mentioned we had a
14 discussion about this at the subcommittee and I
15 mentioned at that time that we would certainly take
16 that onboard and go back and look to see what we could
17 do in that regard.
18 MEMBER STETKAR: Thanks.
19 DR. KANNEY: Your observation is, I mean,
20 it's accurate. I've seen it happen. Say for example
21 the update to this Reg Guide in many places relies on
22 work that PNNL did in NUREG 7046. And in that NUREG
23 CR they have example calculations to sort of
24 illustrate the methods and things.
25 And I was, I guess initially I was

surprised, I'm not sure why I was surprised looking back on it. But I was talking to one of the licensees and they took a set of examples out of the Appendixes, oh okay, these are the things we must do. I'm like wait a second, those are illustrative examples. That wasn't a command.

MEMBER SCHULTZ: And that should be stated very clearly as part of the text as well as the appendix, because for all of the stakeholders that can become the assumption of how the analysis is to be performed, or reviewed.

DR. KANNEY: Quickly, I just wanted to throw this slide up here just to sort of show the breadth of interest in the Agency in the guide and the number of different entities that we have talked to in the course of developing the guide and then have involved in the concurrence reviews.

And to tell you the truth there are a few folks that popped up after the guide was written and they said, hey we use it for this and this thing over here. And I'm like oh, wow, I didn't know you used it for that. So I learned some things about who actually uses the guide that I wasn't aware of when I first waded into this.

MEMBER STETKAR: I think, Joe, that in the

interest of time, I know you had a few slides on probabilistic flooding hazard analysis and from our first discussion you know that the Committee's quite interested in that.

But in the interest of time unless there's one or two very quick points that you'd like to make from those slides, we just don't have time to go through all of them. So if you have one or two very, very quick ones I think we'd like to hear it.

DR. KANNEY: Right. I don't even need to put those slides up to talk about them. One is just that we are, in research we are actively discussing with the licensing office how we can put the flooding hazard analysis. Incorporate more probabilistic methodologies and concepts into this area. Research is sponsoring some outside research right now. We have one project started on probabilistic rainfall modeling.

We have a couple other projects that we're just getting started on that address riverine flooding. And these are sort of, you know, these projects are not going to answer all the questions. They're getting us started on some key mechanisms that we know will feature in a more broadly constructed probabilistic flood hazard assessment approach.

One of the other things I wanted to point out. That is in order to sort of map out the areas which we think need more work or are mature and the research the NRR and NRO are jointly sponsoring a workshop in January on probabilistic flood hazard assessment. It's also going to be cosponsored by several other federal agencies, Bureau of Reclamation, Corps of Engineers and the U.S. Geological Survey. And we're also talking to some other folks as well.

The point of this workshop, at least from NRC's point of view, what NRC hopes to get out of it, is to bring in people who are using some of these methods now. Look at what areas are ready to go and can be used right now, identify areas which may need further research in order to be applied to the type of extreme floods that we are interested in. And then use that information to really formalize a research plan going forward to provide a good technical basis for developing guidance in this area.

I'm done.

MEMBER STETKAR: Thank you. Do any of the members have any questions or comments? If not are there any members of the public that would like to make any comments or statements. If not I owe you three minutes, Mr. Chairman, it's back to you.

CHAIR ARMIJO: How about bridge line? Do we have anybody?

MEMBER STETKAR: I wasn't aware. We didn't have any requests for statements.

CHAIR ARMIJO: All right. What I'd like to do is take a break now and reconvene at 10:20.

(Whereupon, the meeting in the above-mentioned matter went off the record at 10:01 a.m. and went back on the record at 10:19 a.m.)

CHAIRMAN ARMIJO: All right, we would like to reconvene and Dr. Mike Ryan will lead us through this briefing.

MEMBER RYAN: Thank you, Mr. Chairman. On July 10th, 2012 the Radiation Protection and Nuclear Materials Subcommittee heard presentations and held discussions with representatives of the NRC staff, EPRI, and NEI on ISG-8, Revision 3, Burnup Credit to the Criticality Safety Analysis of PWR Spent Fuel and Transportation and Storage Casks.

The version that the Subcommittee reviewed was the draft prior to public comments. The entire committee recently received the final draft that incorporates the Subcommittee and public's comments. And with that, I'll proceed and turn it over to Meraj. You want to lead us off?

MR. RAHIMI: Yes.

MEMBER RYAN: Okay, great, thank you.

MR. RAHIMI: Well, thank you very much, Dr. Ryan. Good morning. My name is Meraj Rahimi, I'm the branch chief for Criticality, Shielding and Dose Assessment Branch in the Division of Spent Fuel Storage and Transportation in NMSS.

This morning we're going to go over an overview of the Interim Staff Guidance 8, Revision 3 that we are about to issue the final version. And I'll provide some backgrounds and I'll have Drew, the lead technical person, to present the main changes that were made to the guidance, the ISG-8, Rev. 3.

And Nate Jordan, from my staff, he'll cover the misload analysis. So with that, let's go to the next slide, please. Just a little bit of background, maybe I'm going way far too back with this slide.

MEMBER SHACK: Radiation and heat, all right.

MR. RAHIMI: So just to bring it into context really, why burnup credits now, on the reactor side and the pool sides, melted using burnup credit for a long time, what has happened with the storage and transportation cask designs.

But the older generations of these casks that were designed for really younger and cooler fuel because the anticipation was that maybe another fuel was going to pooled for a few years, then it's going to be shipped off to reprocessing facility.

And so you look at the older generation of the cask, it was designed for like a one-year-old cooled fuel. So it was high heat, high radiation, and those were the drivers for the design. Criticality safety wasn't a driver because they had to separate out these fuel assembly anyway in order to meet the peak clad temperature.

So having a separation between fuel assembly, they even made a conservative assumption the fuel is fresh. That way they didn't really have to go to trouble analyzing. So it was a very conservative assumption.

But then over the years, I think in the late 80s, in the 90s, then it was realized yes, these fuels are going to stay in the pool for a long period of time. And we have to go into apply storage and subsequent transfer, maybe a number of years from now.

Payload became a criteria, going to a high payload capacity casks. And as a result these fuels were older fuel and colder. So subcriticality came

into the scene becoming a design driver. Because they wanted to increase the payload.

How did they increase the payload? Next slide, please. They basically bringing assembly closer together because these are the longer and colder fuel. So they couldn't no longer afford their fresh fuel assumptions. It was too conservative.

The vendors wanted to take credit for the fact that the fuel is burned. Because once you bring the, it became more like core now, that they had the assemblies in there. But they still had a design with poise in place in between fuel assembly and they got rid of these, what we called the flux traps. And it was spacing in the fuel assemblies.

So just started asking, submitting application with burnup credit. So the staff and that's basically, a burnup credit in really taking credit for the depletion of the fissile isotopes in the fuel, and the production of neutron absorbing isotopes, which include some actinides and fission products.

And that's really the burnup credit, the term burnup credit is referred to, is taking credit for the depletion of the fissile isotope reduction of neutron absorbing isotopes.

So the staff had to, in the early 2000, provide some guidance to our reviewers, that when you get an application you have to review this. Because it is no longer fresh fuel assumption.

And the staff had to now look at the operating history, the radiation exposure, the fuel being in the core, so we have to go on the reactor side now, how this fuel is less reactive. Because the reactor operating conditions have a lot of affect on how the reactive that discharge fuel assemblies are and what are the assumptions that are made.

So in early 2000 the staff issued a guidance based on available data at that time, which said that at this point that there is an update for the vendors and the designers to take credit for the actinides, the reduction in the fissile isotopes, and the production of the neutron absorbing actinides, like Pu-240, Pu-242.

Because there was enough chemical assay data from the program that was done at PNNL. Although the purpose of the chemical assay was really for more disposal. But there was enough data about the chemical assay and we had enough critical experiments with these isotopes that we knew very well.

These isotopes were started for many

years, U-235, Pu-239, these are the important isotopes, so we really had enough data, were comfortable putting out a guidance and yes, there is enough data. We believe that you can take credit for actinides provided you follow this procedure.

And then as we got more applications in early to mid-2000 about going beyond actinide, because actually the actinides credit really didn't buy the fuel vendors much, still there were a majority of the fuel assemblies that they couldn't fully load, full capacity in a cask.

You could always transport fuels, check a vort pattern, no burnup credit, can always trap or store. Again, the idea was to increase the payload and fill up these casks because dry storage, due to these fuel in a dry storage.

And these are expensive systems and you don't want to half-load it, or you don't want to half-load transport and have too many shipments. So there was an SRM that came from the Commission, and kind of directed the staff that they should focus on efforts on using burnup credit.

And recognize that yes, that is going the right direction. But we need to go further in burnup credit. And especially, there was a letter from this

Committee that was sent in 2008 Chairman Klein and it recommended that the staff should take a more risk-informed approach for evaluating burnup credits.

And really the focus was, at that time, our position was there was an update on actinides only, but not an update on fission products that the liquids give credit to.

But the recommendation from the Committee was, we should take a more risk-informed approach. And although, you might not have all the data that you need but take a risk-informed approach.

In pursuit of this approach, and the staff did follow these recommendations. And for the past several years, past three, four years, the staff, with the help of the National Labs we embarked on really looking at the going beyond actinides only.

Okay, what does it take for the vendors to take credit for the presence of these fission product isotopes? Although, we might not have the critical experiment, all the critical experiments we want, all the chemical assay that we want But is there a method or a technique that they could use in order for them to take credit in the presence of these neutron absorbing isotopes.

So in May 2012 we, with the help of Oak

Ridge, we issued NUREGs on the techniques, on the methods. And we're in a position to revise ISG-8, Revision 2, which was actinide only, now provide guidance going beyond actinides only, now you can take credit for fission products.

So that's basically the scope of these ISG-8, Revision 3, that now is going beyond actinide only, and plus other changes that are based on the experience on the applications that we received, we deemed it necessary to make some other changes.

So Drew, now, will highlight what are the major changes that were made to the ISG-8, Revision 2. Drew?

MR. BARTO: Okay. And I am Drew Barto out of Division of Spent Fuel Storage and Transportation at NMSS and I work directly for Meraj. And we have worked on this issue together for some time. And as he said, I want to walk you through the major changes to the ISG in this revision, since the last time we revised it in 2002.

We've done a great deal of research through our National Labs, particularly Oak Ridge National Lab, in coming up with new data and new methodologies for co-validation to support credit for minor actinides and fission products.

So this version of the ISG recommends taking credit for 20 additional minor actinides and fission products. And I'll talk about that in some detail later.

There was also sufficient data to allow credit to be extended up to 60 gigawatt days per metric ton. It was previously 50. And the main driver for that was in the radiochemical assay data. And I'll show where we've got more data in that range to support this level of burnup credit.

We have also looked at misloads in casks. Our previous version of the ISG had a recommendation that measurement be performed to confirm the burnup value of that assembly. And this was primarily to prevent misloads in casks. We've looked at that issue some.

And this revision of the ISG provides an option to perform a misload analysis and it will incorporate additional administrative loading procedures in lieu of a direct burnup measurement.

So as I said, we've had a great deal of work done since 2002 looking at the burnup credit issue. And this is really just a sampling of the NUREGs that have been put together by Oak Ridge National Lab.

The first bullet there, NUREG/CR-6979 discusses a set of data that we were able to purchase from the French, that consists of high quality actinide critical experiments.

And these were critical experiments designed to look like the uranium and plutonium composition of 37 ½ gigawatt a day fuel. And this was evaluated by Oak Ridge National Lab, and found to be very applicable to burnt fuel compositions in a spent fuel cask.

And we didn't have any of this data before. We were relying almost entirely on fresh U-02 critical experiments and mixed oxide critical experiments. So this was a great improvement in the validation set for criticality.

There was also a good deal of work done since 2002 on the depletion code validation side, particularly in generating radiochemical assay data from destructive spent fuel measurements. And this is primarily what we used to validate the depletion codes.

And this NUREG-7012 here is a summary NUREG of four or five other NUREGs that detail specific programs to generate this data, that are far more recent.

The last two NUREGs on this list, I'll talk about in a little more detail but basically we consulted with Oak Ridge National Lab. They found a way basically to use all of the data that was at our disposal to develop new code validation methodologies, both for depletion and criticality. And they actually provided some reference bias and bias uncertainty values that can be used under certain conditions directly by applicants.

So we felt that the availability of this French actinide criticality data gave us a much greater degree of confidence in the criticality validation that existed when we issued the previous revision.

And the actinides, those major actinides, that are represented in the newest experiments account for roughly 75 percent of the reduction in K effective due to burnup. So that's an important part to validate properly.

And we felt that since you can now do that, it's appropriate to move forward with fission product credit. There is a much better database of radiochemical assay data that supports burnup credit to higher burnups.

All of this available data was used in

these two NUREGs to develop alternative depletion criticality code validation methodologies, and reference bias and bias uncertainty numbers. So we revised the ISG to recommend crediting both actinides and fission products up to 60 gigawatt days.

MEMBER SHACK: As a matter of curiosity, is this the longest lasting Interim Staff Guidance available?

MR. BARTO: I don't believe so. It's number 8. There is several others that I think are going for more -

MEMBER SHACK: It's still active?

MR. RAHIMI: ISG-01, do we have ISG-01 too?

MALE PARTICIPANT: Yes.

MR. BARTO: And some of them have been incorporated into, there is one SRP that went final that incorporated a large number of them. And there is one that is under revision right now.

MEMBER SHACK: What would it take to turn this into an SRP? I'm just sort of wondering where you're at here.

MR. RAHIMI: Yes, actually, when we were revising the SRP, our storages were about to incorporate all the things that we had in ISG-8, Rev.

2 into this. I think we present it to the Subcommittee.

And the recommendation was well, you're still changing that ISG, your position, so why don't you wait until your position is final. And the new revision, and wait, then incorporate. So that's the reason, about three, four years ago we didn't incorporate that one.

And the plan is, right now, we believe kind of this is complete on the burnup critical PWRs. And the plan is, I think within the next couple years, we're going to revise our transportation SRP, so that with the Palisades we're going to incorporate all of this stuff into the SRP. And that's the final.

MR. BARTO: Yes, and the ISG has evolved since the last time we did this. This particular ISG, I was looking back when we started this process and trying to figure out what the process was when we issued Rev. 2.

And the process was basically, we developed it internally. And SFST director signed it out and it was done. So there is a lot more steps now and it's -

MEMBER RYAN: I'm going to suggest we press on.

MR. BARTO: Yes. Okay, we coordinated with NRR and NRO, since they also have burnup credit issues in the spent fuel pools, to have this work performed by Oak Ridge National Lab to develop these new depletion and criticality code validation methodologies.

As I said before, they provided the methodologies and they also provided reference bias and bias uncertainty values for a, it's a fictional storage and transportation system. But it's one designed to look very much like what we're seeing.

And they also did the same for the criticality code and came up with a reference bias value. And they provide recommendations on how to use these reference values and what the criteria are for being able to use those values.

And then also, if an applicant doesn't meet the criteria for using those values directly, then there are methodologies described in detail on those NUREGs that can be used to develop those values on their own.

These next few slides I took from a presentation at the subcommittee meeting that was done by Oak Ridge National Lab. And I'm going to attempt to summarize the validation methodologies that were

developed. But this is a much shorter presentation about validation in general.

So we can talk about this as much as you want. But the validation methodology that was developed for the isotopic completion code is knows as the Monte Carlo uncertainty sampling method.

It uses all of the available and applicable radiochemical assay data to develop, for each nuclide, a composition bias and bias uncertainty. In other words, the code calculates that you have X amount of U-235. Based on the measurements that you have, what's the bias on that code calculated value? And then what's the uncertainty on that bias?

So using that for each nuclide, you can define a distribution of values. So what this methodology does is you basically develop a model of you cask system, or your pool system, and calculate the composition for a particular burnup and enrichment value.

And then use this methodology to randomly, but according to the normal distribution, adjust that value. So it's based on the uncertainty of the composition bias for each particular nuclide.

So there is 28 nuclides that you're modeling in this system. Each of them are

independently varied. So you do this for one K effective calculation and then you repeat that process for hundreds of criticality calculations.

And then what you get is that example on the right there, where it converges to a K effective value, which determines what is the depletion code bias in terms of a delta K effective.

And then the upper and lower bounds there represent the standard deviation of that bias, in terms of delta K effective. So this is a way of estimating what the bias is in terms of K effective.

And again, the basis for this is this database of measured radiochemical assay data. These are the 28 isotopes that are recommended for burnup credit and it gives you an idea of what the number of samples are that you have.

So you can see for the major actinides, you have a lot more measurements. Basically, every sample that is used has U-235, 238, and most of the plutoniums, since they are very important to reactor operation and to any other operations with spent fuel.

Some of the other minor actinides and fission products however, we didn't really start measuring until later. Many of them aren't really important for reactor operation and, in fact, aren't

even there as the distribution of the nuclides changes as the fuel cools. And things that are important at five years are overwhelmed by other more important things that quickly decay away.

So it's a limited set that we're using but the sampling methodology will work for these lower numbers of samples. What it does is it expands where you sample from and it drives out basically the tails of that distribution.

And there was a question at the subcommittee meeting that I wanted to address here. And that was specifically about the measurement techniques, and when that sample was dissolved, how do they ensure that they've gotten -

MALE PARTICIPANT: Got it all.

MR. BARTO: -- everything. So there is an OECD report that details best practices for doing these dissolutions and measurements. And there is a good amount of detail about ensuring that you've gotten everything that you think you have.

Basically, they cut a section of a fuel assembly out and they dissolved the whole thing, clad and all. And then any undissolved clad, they do an analysis to ensure that it's clean material and that they didn't leave anything behind.

CHAIRMAN ARMIJO: Yes, that was my question. I didn't know that they dissolved the cladding, so I thought it might be missing what was deposited on the ID of the cladding, could be important.

MR. BARTO: Sure, no it would be for the isotopes that that would happen with are important. So it's very important that you get everything that you think you have.

There is also an issue any time one of these measurements is done with the metallic residues and I think this was said at the meeting before. But basically, some of them are retained in the dissolved sample but some of them are left over a solid. So you have to basically analyze both sets and combine the answer to get the correct concentration.

And then this is an example of the results that were provided by Oak Ridge National Lab in NUREG/CR-7108, and this is a isotopic K effective bias uncertainty using ENDF/B-VII data.

And what they found is, for a cask system the bias, in terms of K effective, is zero. And what that really means is that the code basically over-predicts K effective in terms of how it handles depletion. So when you over-predict you don't get

credit for a negative bias. It's always set to zero to be conservative. And that's what they found. It was a small over-prediction.

But what really is important here is this bias uncertainty is reasonably large. And it varies as a function of burnup. And you can see that they've reported it for actinides only and for actinides and fission products.

And in terms of delta K, you're varying anywhere from one and a half to three percent, in terms of K effective. And a lot of that is driven by the measurement uncertainties themselves. And the kind of limited set that we have to work with.

CHAIRMAN ARMIJO: Drew, I want to just ask a question for curiosities. Do the fission gases contribute significantly to the, do you treat them or is it -

MR. BARTO: We don't credit them.

CHAIRMAN ARMIJO: You don't credit them -

MR. BARTO: We assume that they're gone.

CHAIRMAN ARMIJO: Okay. But they are there? You had lots of fuel that has leaked.

MR. BARTO: Potentially, for transportation, we have to consider that there is transportation loads that, even if it was intact when

it goes into the package, it may, through either normal conditions or an accident condition, we have certain assumptions about how much of that additional fuel would fail and release those gases.

CHAIRMAN ARMIJO: But let me ask my question in a way, if these noble gases were still there and were credited, would it make any significant difference?

MR. RAHIMI: Well, yes, the answer to your question, if they were there. But due to pinholes, hairline cracks, inherently on the cladding, our assumption is you can not rely on these gases to be within the rod, to stay within the rod.

CHAIRMAN ARMIJO: But you do know if you have a failed fuel element.

MR. RAHIMI: Pinholes and hairline crack is not considered failed.

CHAIRMAN ARMIJO: They leak.

MR. RAHIMI: Right. But we don't define in our definition of the failed fuel assembly, you know, does not -

CHAIRMAN ARMIJO: That means you have some assumption whether the fuel rod is sound or not, we will not credit the fission gases.

MR. RAHIMI: Right. We do not credit

fission gases. Again, because we believe that, generally, you have hairline cracks and pinholes -

CHAIRMAN ARMIJO: That's absolutely wrong. You don't generally have hairline cracks and pinholes in spent fuel, that you don't know, it may be a very rare situation where you have a failed fuel that's not leaking somehow. But that's extremely rare. But the reality is -

MR. RAHIMI: Right.

CHAIRMAN ARMIJO: -- most spent fuel is sound and the fission gases are in the fuel rod there some place.

MR. RAHIMI: And also, there are three criterias that we really, how we come up with these 28 isotopes. And also, you have to be stable, you know, stabilized topes.

CHAIRMAN ARMIJO: Sure.

MR. RAHIMI: And non-soluble, so there is a set of criteria that we run these isotopes through, that you know for tens of years, or 100 years, you know these isotopes are going to be here.

CHAIRMAN ARMIJO: Yes, that's what I was asking. I don't know the physics enough, that if these things decayed away so they would --

MR. RAHIMI: That's really give you any

bad gases in 20 years, not stable --

MEMBER RYAN: Due to decay.

MR. RAHIMI: Yes, due to decay, that some of those fission gases, krypton gases.

CHAIRMAN ARMIJO: So maybe the answer I'm looking for is yes, they're there initially but they decay away --

MEMBER RYAN: As I recall a comment -- Meraj, correct me if I'm calling this wrong -- that while they're there and as they decay away mainly, the point was made that they're not going to be around long enough to do a lot of good. It's really chasing a really small incremental --

MR. RAHIMI: That's right.

MEMBER RYAN: -- contribution, so I think that's where it ended.

CHAIRMAN ARMIJO: That was, I think, were they significant or not, while they might be, but not very long.

MR. RAHIMI: Right. Yes, and we had actually some application that we saw that the applicant was taking credit for krypton, for example.

CHAIRMAN ARMIJO: He didn't last very long.

MR. RAHIMI: Look at the half-life, you

know, it's not there.

CHAIRMAN ARMIJO: Okay, thank you. I won't -

MR. BARTO: Yes, it's not clear how important that would be, either it's another fission product, it would probably be kind of down in the weeds, so to speak -

CHAIRMAN ARMIJO: Okay.

MR. BARTO: -- as far as contribution of delta K.

MEMBER SCHULTZ: It's been a matter of choosing a reasonable set that will have an impact, but cause no question -

CHAIRMAN ARMIJO: Right.

MEMBER SCHULTZ: -- associated with protecting the reactivity of the gas.

CHAIRMAN ARMIJO: Okay.

MR. BARTO: Okay.

MEMBER RYAN: Tempus fugit.

MR. BARTO: So the second NUREG that Oak Ridge National Lab developed was about estimating criticality bias due to the additional minor actinides and fission products that we wish to credit.

As we've stated before, we've got a good set of critical experiments for the major actinides.

But there really isn't sufficient data, in terms of critical experiments, that involve the minor actinides and fission products. At least not what we would typically expect for criticality validation.

So what Oak Ridge did in their NUREG is develop a methodology for estimating what this bias could be based on the cross-section uncertainty. So in the ENDF file there are estimates of what the cross-section uncertainty is as a function of energy.

And what Oak Ridge has done is they have used sensitivity data, basically, for every criticality model you can generate this sensitivity data. And what it tells you is, what is the change in K effective due to a change in the cross-section data, as a function of energy.

So when you multiply the cross-section uncertainty by this sensitivity data, you can get an estimate of K effective uncertainty. And the basis for this approach is that code biases are primarily caused by nuclear data uncertainties.

And the NUREG has a large section about verifying that this is actually true. And it is true in almost all cases. And this therefore, gives you an upper bounder for what the magnitude of the bias could be, since we don't have any critical experiment data

to actually determine a bias.

So they determined this uncertainty in K effective for a variety of systems and they did a large sensitivity study on this. And what they found was that the uncertainty is never larger than one and a half percent of the reactivity worth of the minor actinides and fission products.

So then this is a, using this one and a half percent value, gives you an estimate of the bias as a function, essentially as a function of burnup. And then for each NUREG, Oak Ridge offered recommendations for how we were to use this.

And we've essentially taken their recommendations that applicants can use the reference bias uncertainty numbers in lieu of performing an explicit validation, provided that they are using the same code and cross-section data. And that their storage or transportation system is similar to what was evaluated in the NUREG/CRs.

And they chose the systems in the NUREG/CRs to be representative of what we're typically seeing. And then for the major actinides, the applicant should perform a traditional criticality code validation using that HTC data.

So for code validation in ISG-8, this is

a summary of what we're recommending. Again, they performed the major actinide criticality validation in, more or less, the traditional way validation is done. But for minor actinides and fission products, for the criticality bias, they are to use the Oak Ridge supplied bias number.

And for isotopic depletion analysis for both major actinides and minor actinides in fission products, they can either use the Oak Ridge supplied bias and bias uncertainty numbers or use those methodologies that were developed in the NUREG to determine their own estimate. So that covers validation in the ISG.

We also made some changes in the burnup confirmation section of the ISG, done a good deal of work looking into the misload issue in casks. We have a NUREG developed that looked at well, what are the potential consequences of a misload.

So this NUREG evaluated from under-burned all the way to fresh fuel assemblies loaded in the worst case position in a burnup credit cask. And the key result out of that was that for a single fresh assembly, can give you as much as a five and a half percent increase in K effective.

Now there is obvious physical differences

between fresh and burned assemblies. But a severely under-burned assembly can get close to that. So it's something that we felt we needed to address in the ISG.

Another NUREG that looked at basically how burnup information is determined normally in reactor operations. And then compared those methodologies to the out of core measurement techniques that had been performed to-date, such as the fork detector that's used in pools sometimes to determine burnup.

And we also had research look into this issue and they have a report that they have developed for us that estimates the probability of a misload in a spent fuel cask. That was out just last year.

And the key conclusion from that report is that these are credible events that we have to consider. So what we've done in ISG-8 is, we've recognized that fact but we've allowed an alternative to the measurement. And that alternative consists of a misload analysis combined with additional administrative procedures for burnup credit casks.

So the ISG goes into detail about what kinds of misloads are to be evaluated. In looking at the events that have happened, it became clear that we should think about more than just a single misload, as

Nate will get into in a moment. Most of them have involved multiple assemblies within a cask.

But there is still the oddest assembly out there, that is severely under-burned and that means a higher enriched assembly that has gone through typically less than a full cycle of burnup, an assembly that was pulled out for whatever reason early in the cycle.

So we've developed a criteria that the applicant should evaluate a single severely under-burned misload. And that misload should be chosen, such that the fuel reactivity bounds 95 percent of the under-burned fuel population with 95 percent confidence. And by under-burned I mean fuel that does not meet the cask loading curve.

For the multiple moderately under-burned misload, the assemblies should be chosen such that half the cask is filled with a fuel assembly that bounds the reactivity 90 percent of the total discharged fuel population.

So that's out of all of the discharge assemblies that can be loaded in the cask. And I've got a graphic in a moment that I will show that will kind of illustrate this.

And we're also accepting a reduced

administrative margin for this analysis since it is an upset condition. And I'll talk about that a little bit later when we get into the public comments.

And then we recommended additional administrative procedures that we would believe would reduce the likelihood or the consequences of a misload, such as identifying the location of high reactivity fuel in the pool prior to and after loading, before hand, to recognize where it is.

And then afterwards to make sure it's still there and not in the cask or independent reviews of the cask loading process. And there is a set of procedures that we recommend and this is just a sample.

So with this single misload and the multiple assembly misloads, this is to illustrate kind of what we're talking about here. The green line, it's not a real loading curve but it's sort of what you might expect would be typical of a spent fuel cask loading curve, meaning that fuel above that line is acceptable for loading. And this cloud of numbers represents the entire discharged PWR fuel population as of 2002.

So the red line at the bottom is what you might expect of a fuel assembly that bounds 95 percent

of the under-burned population. And that's a line of equal reactivity. And as you can see, in reality, there is only a handful of assemblies that are under that line.

CHAIRMAN ARMIJO: Wouldn't those normally be damaged fuel that was -

MR. BARTO: Probably.

CHAIRMAN ARMIJO: -- either leaking or something was wrong because there is -

MR. BARTO: Probably.

CHAIRMAN ARMIJO: -- not much incentive to leave -

MR. BARTO: Well, what you find when you get in and actually look at this data, is a lot, you kind of can't really see those numbers but there is more than one in each of those -

CHAIRMAN ARMIJO: I know there's -

MR. BARTO: -- boxes.

MEMBER SKILLMAN: I think I know that eight of these are lead test assemblies that were in for one cycle instead of three -

MR. BARTO: Right, that -

MEMBER SKILLMAN: -- fuel cycle said that if they're five weight percent, that only got consumed for -

MR. BARTO: That may be the case but below that line, at that enrichment, is well less of what you would typically expect for even one cycle.

CHAIRMAN ARMIJO: There has to be something strange, in that people would know -

MR. BARTO: Right.

CHAIRMAN ARMIJO: -- about those.

MR. BARTO: Right. And that's the idea. And when you look at these, more often than not, you find that a grouping of assemblies is all at one site. So there are many sites that might not have any assemblies below this line. And they have the option of doing a site-specific type analysis that would be much less penalizing, I think, in terms of K effective.

So the blue line represents what you might expect for assemblies that bound 90 percent of the total population. Key point about that line is it's conceivable that a cask loading curve would already be below that line, in which case this evaluation wouldn't have to be done. So unless there is any --

CHAIRMAN ARMIJO: Just a quick question.

MR. BARTO: Sure.

CHAIRMAN ARMIJO: Are MOX assemblies, they're not many of them, but I know there were some

MOX assemblies that were recently discharged a little prematurely, after only one cycle or two cycles?

MR. BARTO: If it was discharged before 2002, it's reflected in this database.

MEMBER SCHULTZ: It is in the database.

CHAIRMAN ARMIJO: It is?

MEMBER SCHULTZ: Yes, two cycles versus three.

CHAIRMAN ARMIJO: Yes.

MR. BARTO: And just a word about this database, it's an energy and information administration fuel survey, which they have done a number of times in the past and they keep, as early as 2006, they were supposed to redo this and they have not done this. So we're looking for an update to this data whenever we can get it.

CHAIRMAN ARMIJO: Yes, I would be curious to see this same plot for BWR fuel.

MR. BARTO: And that's in the database too, up to 2002. And we can get that. And we'll talk a little bit about BWR fuel later on. But unless there is any other questions about this material, I'll -

MEMBER RYAN: Drew, we're about half way there and we've got a lot of ground to cover.

MR. BARTO: Okay, I'll turn it over to Nate. And Nate is going to talk about the misload report.

MEMBER SCHULTZ: Thank you.

MR. JORDAN: Good morning, sirs, ma'am. My name is Nate Jordan. And just like Drew Barto, I work directly for Meraj Rahimi. And I've been involved sometime with them, as well as other staff in SFST in Research on this effort.

Just wanted to talk to you briefly about the misload report that was generated by Research. And due to a collaborative effort between both, the report was generated which looked at the probability of having single and multiple misloads.

Other objectives of that report also included identifying causes, possible causes of misloads, as well as any common mode failure.

Two approaches were used in the -- and if I'm talking too fast, please -- but two approaches were used in the report. One of which involved the empirical approach, which used real-time data involving a misloads in the industry just to give some idea to the extent to which misloads do occur.

The secondary approach that was used in the report involved a theoretical approach, which used

a topping event tree model. The event tree model is beneficial in identifying areas in the loading process where misloads can occur.

And also, providing some idea of potential checks and reviews in the loading process that could help to avoid those misloads. The report also looked at the impact of a burnup credit, the impact of assembly burnup on the probability of having a misload.

From the briefing given to the Subcommittee, there were five events that were discussed as part of the probability report.

The first event, Palisades, involved misloading 11 assemblies in five casts. This was really due to cooling times that were used that were based on planned loading dates as opposed to the actual loading dates.

In North Anna and Surry, that was actually dealing with a cask design that was based on asymmetrical loading patterns, based on decay heat limits. Those loading patterns, those cask designs weren't adequately implemented into the procedures that were used in the loading selection process. And that, as a result of that repeated errors, 19 assemblies in 11 casks.

Where Grand Gulf, they improperly used the database that contained incomplete information regarding fuel cycle dates. So as part of that, the result of that was 34 assemblies that were misloaded into four casks during that time.

McGuire was included in the report, only from the standpoint of just showing that it was considered a near-misload, in the fact that an incorrect assembly was picked up that was right next to the correct assembly. But it was caught as part of a check before lowering it down into the cask.

And as you see at the bottom, the results of the empirical calculation in the report, it gives you a misload probability on the order of 10^{-2} if you consider 20 casks are being misloaded out of a total of 1,200.

MEMBER BROWN: Before you go on, what -

MR. JORDAN: Yes, sir?

MEMBER BROWN: -- as a result of the misloads, what was the real K effective that you ended up with? And what's the limit that you would normally shoot for? I saw the other curves and what the burnup thing is trying, I'm trying to understand what is the basic limit in a cask storage cask. Is it .9? Or is it .8? Or is it .99?

Obviously, the object here is to try to squeeze as many as you can and reduce the number of storage casks that you've got sitting around. Is that the purpose of this?

MR. JORDAN: Well, one of the things you want to consider is that you actually want to keep it subcritical dealing with -

MEMBER BROWN: I understand that.

MR. JORDAN: -- and that's going to be dealing with a number of different issues dealing with the subcritical margin and so forth. One of the things to keep in mind with these misloads is that they didn't challenge criticality safety at all. They were mainly based on challenging decay heat issues. I don't know if I answered your question correctly.

MEMBER BROWN: Oh, no.

MR. JORDAN: Oh, I apologize.

MEMBER BROWN: What is the K effective that you want relative to one I guess. Obviously, you have decay heat limits, and you have the K effective limits.

MEMBER RYAN: What's the typical K effective in a loaded cask, is the question you might want to ask.

MEMBER BROWN: Yes, thank you.

MR. JORDAN: I know in some cases you have a .95. But based on the USL, the upper subcritical limit, you could have certain cases depending on the minimum subcritical margins, the bias that's included as well. And so typically you shoot for around .95 in a criticality cask.

MR. RAHIMI: Yes, that's the design, .95. And typically, what you see in criticality analysis that they present, the numbers, they're right up there. Because what they're loading, high enriched, five percent enriched fuel under the flooded conditions, they're right up there.

And that's why the loading curve, you see it goes right smack in the middle of the fuel populations. So that is a .95 K effective line, what Drew put out. So typically, the bounding case analysis that they present, it is up to that point.

But, of course, the actual loading date, they load, yes, often times they are far away from that. But in the certificates that we issue, they can't -

MEMBER BROWN: They're allowed to go that far.

MR. RAHIMI: They can go up to that far, that's right.

MEMBER BROWN: So if they did and you had these types of errors, what would the real K effective be in those circumstances? Did anybody look at that?

MR. RAHIMI: In this specific misload, you're saying, did we look at the -

MEMBER BROWN: If they were at .95 and they made these, based on their calculations, and they made these errors, where would they be when they loaded them? That's all.

MR. RAHIMI: Fortunately, see these casks, these are not the burnup credit casks that were loaded on the storage side. They assume during the loading in the pool, they rely on the boron in the pool. So it is a boron credit that they're using. But if these casks were to be used -

MEMBER BROWN: No, I'm trying, let me, they made errors.

MR. RAHIMI: Yes.

MEMBER BROWN: So now if they made these errors, regardless of the other thing, if they made these errors and they had done their calculation based on .95, what would it have been if they had made those errors?

MEMBER RYAN: Let's turn the question around, try and make it simple.

CHAIRMAN ARMIJO: He answered it earlier.

MEMBER RYAN: If anybody exceeded .95 -

CHAIRMAN ARMIJO: Less.

MEMBER RYAN: -- K effective in a real pool's misload. What's the highest number that anybody has figured out, after the fact, that a misload costs. Is it .94 or .99 or what? That's the question.

MEMBER BROWN: Yes.

MEMBER RYAN: Okay, so now -

MEMBER BROWN: We know they've made errors. And they've got big errors in some of these cases, 34 assemblies.

MEMBER RYAN: What's the question? We're running short of time, Charlie.

CHAIRMAN ARMIJO: Yes.

(Simultaneous speaking)

MEMBER BROWN: I'm trying to figure out why we pushed the limits.

CHAIRMAN ARMIJO: Nate answered the question earlier.

(Simultaneous speaking)

MEMBER RYAN: That's my point.

CHAIRMAN ARMIJO: Charlie, if the question was addressed, he said in these particular misload

events, the criticality does not above, it was lower actually.

MEMBER BROWN: They were low in terms of the, I mean, I presume they were low enough that they didn't. If they were right up against the .95 limit, that he says they can go to, and they made these errors, would they have been much higher?

MEMBER RYAN: But science doesn't support your supposition.

CHAIRMAN ARMIJO: No.

MEMBER BROWN: What, pardon?

MEMBER RYAN: There is a large body of experience that says they're not at that margin.

MR. BARTO: I think what you can take away from this is, that these were all for decay heat, which means in some sense they exceeded the burnup that they were supposed to because there was no minimum burnup for criticality. Because these were all licensed on a fresh fuel assumption.

So from a criticality perspective, these misloads probably resulted in a lower actual K effective.

CHAIRMAN ARMIJO: Yes.

MEMBER BROWN: But when you change in the basis, right? You're trying to take more credit.

These were done on fresh fuel. And so you have a lot of margin.

MR. BARTO: Right.

MEMBER BROWN: And you're changing the rule so that you have less margin.

MR. BARTO: Right. Well, we have done a report that shows consequences of misloads in terms of putting an assembly in that's under-burned by -

MALE PARTICIPANT: 75 percent.

MR. BARTO: -- ten percent, 25 percent, 50 percent, so we can get estimates of what's kind of the worst case that could happen with a misload? And it's significant. For one, if we go back to, that's for one of those in the lower right hand corner, it can be three, four percent in terms of -

MR. JORDAN: I know in one of the ones that Drew is mentioning, talking about the consequences of a misload, they looked at one scenario involving an under-burned by 75 percent.

And it resulted in a change of about three and a half to four and a half percent increase in reactivity, so for a GBC cask. And this misload, in that particular situation, they misloaded into the most reactive part of the cask as well.

MEMBER BROWN: That's even better.

MR. JORDAN: Right.

MEMBER SCHULTZ: And these events it demonstrates that all the assemblies that were intended to go into the casks -

MR. JORDAN: Yes, sir.

MEMBER SCHULTZ: -- were loaded into the casks.

MR. JORDAN: Yes, sir.

MEMBER SCHULTZ: But what was the -

MR. JORDAN: Some of these were incorrect assemblies based on the decay heat limit. So you had a lot of assemblies in here that were misloaded. They weren't initially intended to go into the casks, based on the certificate of compliance in exceeding the decay heat limits.

CHAIRMAN ARMIJO: What I got out of it, at the Subcommittee meeting, was that the errors are in the front end, in the planning -

MR. JORDAN: Exactly.

CHAIRMAN ARMIJO: -- and analysis.

MR. JORDAN: Yes, sir.

CHAIRMAN ARMIJO: They're not at the back end where I thought, guy picks up the wrong thing. So it's the front end planning, a better job there and better job in review is where you get a -

MEMBER SCHULTZ: That's what I wanted to get to.

MR. RAHIMI: That's right and most of the --

MEMBER SCHULTZ: It's a mismatch between the analysis and the assembly.

MR. RAHIMI: And most of the errors you see, these are first of all, it was revealed to us that it was a multiple assembly, that misload. And it wasn't, as Dr. Armijo described, is not the guy picking up the wrong assembly.

MEMBER SCHULTZ: Right.

MR. RAHIMI: It was the load sheet was wrong.

MEMBER SCHULTZ: That's right.

MR. RAHIMI: The database was wrong. The guy did what the load sheet told him to do.

MEMBER SCHULTZ: Right.

MR. JORDAN: And you were correct in a earlier version, when you talked about crediting the robustness of the Hatfield Hanley procedure itself. But like you said, we found out that a lot of these, especially the ones that cause a multiple assemblies, are based on the selection process.

CHAIRMAN ARMIJO: Right.

MEMBER RYAN: Nate, I guess the data that you're working from is relatively old in terms of this misload.

MALE PARTICIPANT: That is right.

MEMBER RYAN: What's current practice like, can you speak to that at all? Have people addressed this, improved procedures so that this isn't a more probability event, that kind of thing?

MR. JORDAN: Well, we still, believe it or not, and that was one of the points I was going to make later in the presentation. But we, even the day after we presented back in July, we received information on a misload, although a pulled misload, at Indian Point that happened earlier in the year. So misloads do happen.

MEMBER RYAN: I guess what I'm reaching for is what is the frequency of it? Is it getting better? Is it about the same?

MR. JORDAN: Since this data has been included, I'm not sure we really substantiate enough -

MEMBER RYAN: It's kind of hard to tell.

MR. JORDAN: Yes, sir.

MEMBER RYAN: Okay, all right. That's fine.

MR. BARTO: This data isn't all, North

Anna and Surry was what, last year?

MR. JORDAN: Yes, sir.

MR. RAHIMI: Yes, these are -

MR. BARTO: 2011.

CHAIRMAN ARMIJO: So this isn't ancient history.

MR. BARTO: Right.

MEMBER BLEY: Nate?

MR. JORDAN: Yes, sir?

MEMBER BLEY: Just before you got into these events, I looked ahead and I don't see anything on this. You said you were considering the impact of burnup on misload probability. And yet, when I look through this, I don't see anything coming up about that. Can you tell us about that?

MR. JORDAN: Yes, sir. What we were trying to say is that the report looks at the impact of a burnup on probability. And the result is that, the probability is independent of the actual burnup of the assembly itself, but rather the population at particular burnup values.

MEMBER BLEY: Okay. I was just trying to figure out what in the world -

MALE PARTICIPANT: We just mentioned it to break this up.

MR. JORDAN: Any other questions before? All right, one of things we looked at, I know as part of the last briefing to the Subcommittee, the Committee seemed to be interested in information regarding any corrective actions that were implemented as a result of these misload events.

In the case of Palisades, one of the things they did is they added procedures that actually governed or provided guidance on fuel handling selection, as well as they updated the fuel database to include a more up-to-date fuel information. That's one of the things they did as a start.

For North Anna and Surry, they implemented a revise to procedure to include an explanation of the asymmetrical design and how it impacted, or the asymmetrical design based on the decay heat limits, and how it should be implemented into the procedures that were used in the loading selection process.

For Grand Gulf, they added a procedure for developing a database because if you recall, from the earlier slides, the database that they used contained incomplete information. So they added a procedure, which governed how to, or development of the database to contain more up-to-date information.

All right, as part of the report, the

conclusion of the report, we find that misloads are deemed credible based on both approaches, the empirical and the theoretical approach.

As far as the event tree model, one of the things we take away from this is that a lot of the errors seem to be based on systematic or planned, errors in the planning process.

And a lot of the errors, also a lot of the misloads, if you are going to have a misload, more than likely it will include or involve multiple assemblies.

Right now, currently, we're coordinating with other program offices within the Agency, NRR, NRO, and the Office of Research in working with industry to try to minimize the likelihood and the consequence of having misloads, both in the spent fuel pool and the spent fuel storage cask.

CHAIRMAN ARMIJO: I wonder how this compares, misloads and cask loading compares, with misloads to core loading. I think people are really careful loading at core. I don't have numbers but the procedures they would use to make sure that they load the core properly could readily be applied to planning the loading of a cask.

MR. JORDAN: Right.

CHAIRMAN ARMIJO: Assuming that the core loading is more reliable than cask loading.

MR. JORDAN: Yes, sir.

CHAIRMAN ARMIJO: So I was just curious about that, and if you've ever looked into it?

MR. BARTO: I think that's a good takeaway for something we should look at when we're developing this IN.

CHAIRMAN ARMIJO: Yes.

MEMBER SKILLMAN: I'd like to add to that. Very often the IN is not well absorbed in the site culture. Very often the IN is reviewed by the licensee. It could be in the corporate office. But it doesn't find it's way down to the, either the STA or the nukes at the site, that actually are responsible for developing the basis of the planning for the fuel moves.

So I'm wondering, for your first two bullets, if there might not be some benefit to the IN being distributed to a different group of personnel. I spent 23 years at one site and it was rare that the IN found it's way down into the operating floor.

I'm wondering if the better way might be to get it to the reactor inspector for a brief inspection before any fuel moves. If you go back to

the list of errors, each one of those is a preventable human performance error. Each one of those could be prevented.

MR. JORDAN: Yes, sir.

MEMBER SKILLMAN: And I would offer that most of the site people would say gee, we don't want to do that again.

MEMBER RYAN: Dick, I'm jumping ahead a little bit but I think some of this we're going to hear from EPRI?

CHAIRMAN ARMIJO: Yes.

MEMBER RYAN: So a little more detail. So if we could hold those -

MEMBER SKILLMAN: Okay.

MEMBER RYAN: -- follow-up questions for that briefing, I think that would -

MEMBER SKILLMAN: But I would offer this, at some level, in the course of time, the inspectors have become so familiar that they are not always as challenging as they could be.

MEMBER RYAN: Yes.

MEMBER SKILLMAN: And this might be a place where the reactor inspectors at the site get an aggressive path and everybody knows, they are really digging into this. And the site culture would

probably say we accept this. This is a good challenge.

MR. RAHIMI: Yes, that's a very good point. Actually we just, we in the Division, were just finishing a training course for inspectors. And one part of it is the loading. And we're bringing our designers actually, sort of walking our inspectors through these loading patterns.

Because all the designs we're receiving is getting more complicated. Is a loading pattern with inspector heat, thermal, now criticality safety, so you've got three -

MEMBER SKILLMAN: But it also goes to Dr. Armijo's question about loading the core itself.

MR. RAHIMI: Right.

MEMBER SKILLMAN: Placing the expended fuel into the spent fuel pool, into the racks, and then moving from racks over to the storage locations.

MR. RAHIMI: Right.

MEMBER RYAN: I don't want to halt a good discussion but we need to move on.

CHAIRMAN ARMIJO: Yes.

MR. JORDAN: All right, just to finish up, like you said, we are looking at developing an IN to look at misloads in the spent fuel pool and the casks.

Going into this, a couple of things to consider. The fact that number one, we want to communicate that misloads are credible. And the result from systematic failures can involve multiple assemblies.

One of the things we also wanted to look at now, with the advent of burnup credit, along with decay heat and shielding considerations, loading patterns that are already, by some, considered to be complex can become even more complex, which could increase the likelihood of misload events.

And we just want to drive home the fact that efforts to reduce misloads should provide more focus, should have a stronger focus on the planning phase, as well as making sure that your inventory data is correct. And actually, if there's no other questions, I'll turn it back over to Drew.

MR. BARTO: Okay. I'm going to talk about the public comments we have received on the draft.

MEMBER RYAN: Drew, I'm going to have to ask you to either skip a couple slides or move quickly through them because we really are running short on time.

MR. BARTO: Sure. I'll just go ahead and go right into them. We had a number of comments about

providing flexibility for other validation methodologies. EPRI has spent a good deal of time and effort coordinating with the industry on an alternative validation technique that we have not reviewed yet.

So what we've done with the ISG is reinforce the idea that this ISG represents one method that has been reviewed in detail and found to be acceptable. And that we're not going to explicitly exclude alternative methodologies and that we'll review them on a case by case basis.

There was a request to remove the burnup measurement, since we've now offered an alternative to it. We have decided to leave it in as an alternative. This would allow applicants flexibility in case, either that can't meet the misload analysis criteria or for some other reason, they can't verify the burnup, in case they couldn't read the assembly ID number or whatever.

Additionally, we want to leave open the idea that there might be better measurement technologies in the future that would make that option more appealing.

We have a large number of comments about the proposed administrative loading procedures that we

recommended to a company, burnup credit cask loading. There was an alternative set proposed by industry. And there are a couple of examples there.

We looked at that list and felt like those were things that should already be done for cask loading, regardless of whether or not it's a burnup credit cask, and that our procedures were intended to be specific for burnup credit casks and geared towards preventing misloads.

So we've reinforced this in the ISG, that these are additional procedures for burnup credit cask loading. And you can see there is a sampling there on this slide. And we've revised the ISG to remind the reader that these are recommended procedures. We will, obviously, consider alternatives. And this list is not intended to be all inclusive.

We also had a large number of comments on our misload analysis recommendations. We had some words with regards to the reduced administrative margin for the misload analysis. It's typically .05 from a criticality analyses.

But there are other regulations, in other parts of the Agency, for other criticality safety regulations that talk about how you can justify a reduced administrative margin.

And our draft ISG asked for justification for whatever margin is used. So we've simply clarified what that justification should consist of and we've pointed to a much larger, more detailed document as issued by the Division of Fuel Cycle Safety and Safeguards out of NMSS.

For our single fresh fuel assembly misload, we had a recommendation to simplify this and just make it a fresh fuel assembly, which I think that we would find acceptable, if somebody were to submit such an application.

But the fact is we know what to expect from, in terms of a delta K from, fresh fuel assembly misloads. And we don't believe that most systems, that we are licensing today, could meet that criteria.

So what we've developed is what we consider a reasonably bounding single misload, recognizing that there is significant physical differences between fresh and burned assemblies.

For the multiple assembly misload, there was a recommendation that we simplify it to just make it 25 percent under-burned. And that's based entirely on the license loading curve. This could potentially be less restrictive than what we've proposed, depending on where that loading curve sits.

It also could be more restrictive. It depends. But we've decided to keep our 90 percent of the total inventory recommendation, which also allows a licensee or applicant to omit this analysis, if their loading curve already encompasses more than 90 percent of the fuel population.

These are some other assorted comments that we got. We've identified 28 isotopes that we think should be credited. However, we've modified the ISG to state that additional isotopes can be credited if the estimate of the bias and bias uncertainty associated with those isotopes can be provided.

BWR burnup credit, the ISG, as it's conditioned, deals only with PWR burnup credit. We simply have not looked into BWR burnup credit that much. It hasn't really been needed for dry storage casks or transportation.

The reason for this is it's, primarily that it's a smaller cross-section assembly. So if you look at a cross-section in a cask, there is more plates essentially. There is more neutron absorber per volume of fuel. But you generally just need burnup credit less.

However, we have had some applicants express interest in BWR burnup credit. And we have

initiated a research project with the Office of Research in Oak Ridge National Lab to look into this. In the meantime, we've revised the ISG to state that we will look at proposed BWR burnup credit methodologies if they are submitted to us.

We previously limited the recommendations of the ISG to intact fuel only. And that was the Revision 2 recommendation and we had left that recommendation intact for this revision. And we received several comments suggesting that we revise that.

And we have revised it to say that this could be applicable to undamaged in damaged fuel and there is, things have specific definitions in ISG-01, provided that potential fuel reconfiguration and any additional uncertainty is associated with the condition of the fuel are addressed.

We had a number of comments on how we treated bias and bias uncertainty for both depletion and criticality in the draft ISG. For depletion, we had combined bias and bias uncertainty, simply adding them together into one number.

And this is not how these values are typically treated in criticality safety analyses, as was pointed out by several commenters, so we split

them out.

The bias can be added directly to K effective again, with ENDF-VII data this doesn't matter since the biases is zero. But the bias uncertainty that delta case of I is an uncertainty that can be physically combined with other independent uncertainties.

The criticality bias however, it's officially an uncertainty in K effective due to the uncertainty in the cross-section data. However, the ISG recommends that we treat this as a bias, since this number is an indication of how large the bias could be. And we believe it's conservative to treat it that way. So we're leaving that recommendation as is.

We also received a number of comments about the recommendation of how to use that value. We recommend that that estimate of the criticality bias should be one and a half percent of the minor actinide and fission product worth, for the scale code system, using these three sets of data that were evaluated, and that this should be doubled for other codes that used the same data.

We believe it is based primarily on the data but we simply haven't done any investigation of

how other codes would compare. We talk about other codes. We primarily mean MCMP. It's really the only other major code that uses the ENDF data.

And the recommendations that we got in the comments was basically to, we think that we can use this one and a half percent value for other codes. So we investigated this and we've got some additional research underway with Oak Ridge National Lab.

And we may provide some other guidance on this. But for now, we're saying either use this three percent value or provide a demonstration that the one and a half is acceptable.

So in conclusion, we've extended the technical basis for burnup credit to include fission products and minor actinides. We've provided an alternative to the confirmatory burnup measurement in the form of a misload analysis in additional administrative procedures.

This has been generally well received, got a large number of comments but we feel we have appropriately addressed them. And we plan to publish this final ISG by the end of September. And as I said earlier, our next big topic is BWR burnup credit. And we will pursue that next.

MEMBER RYAN: Thank you very much. I

think we'll hold questions to the end. Albert, you ready? Now, Albert, I'm going to rely on you to help us through your slides with some time left for our third presenter from Nuclear Energy Institute. So we'll need to be mindful. You have more slides than the staff did.

MR. MACHIELS: No I don't.

MEMBER RYAN: No, okay.

MR. MACHIELS: No, no. Good morning. First of all, I want to thank the SEIs and the NRC for the opportunity to give this talk on some work that was sponsored by the EPRI members.

I would like to talk with you about the full burnup credit validation, the topic which is obviously of interest today. And I will talk about a alternate methodology. This is not to detract from the work that has been presented by the NRC here. We very much support the progress which have been done in the Rev. 3.

But I think it will provide another view of what can be done in this area. And obviously, what I would like to do is come back on talking about the risk information and the probability of criticality in transportation. There has been a number of questions, comments related to this discussion with misload

analyses.

So let's begin to a brief introduction. Criticality safety is obviously a key public concern. One thing I want to emphasize is that criticality safety came about and was developed originally for shipping material such as enriched uranium, plutonium, and this type of things.

And in all those cases, what you are shipping was fairly simple. Enriched uranium, uranium-235, uranium-238. And in your criticality analysis you have to account for what nuclide you have, as well as the uncertainties associated with the content, what percentage of uranium-235, and also the uncertainty associated with the cross-section with the work.

And that was possible for this type of material. However, when we talk about spent fuel, the same methodology is a little more complex to apply because now we don't have shipments which involve a handful or maybe a dozen of different nuclides.

But we have a shipment which involves a very large number of components. And as you know, ORIGEN follows more or less 2,000 nuclides. But after a short time there is only 400 left or so.

That means if you want to account for

those 400 isotopes the way it is done, typically by looking up each nuclide individually, come up with an isotopic content. Looking at the uncertainty, how will you know the content?

And then looking at the uncertainty of the cross-section associated with that material, and then when you associate all those uncertainty in the conservative manner, then obviously, you end up with very large uncertainties.

So spent fuel, which is something which is much less reactive than, obviously, something like enriched uranium. Also, this has to carry a much larger uncertainty if you want to follow the classic methodology, including basically, taking into account as many nuclides as possible.

MEMBER POWERS: I guess I didn't follow that. You have uncertainties in the cross-section, and you have uncertainties in the content of the radionuclides, so you have numerous uncertainties -

MR. MACHIELS: Yes.

MEMBER POWERS: -- but that doesn't mean that you end up with very large uncertainties.

MR. MACHIELS: Well, you typically do because -

MEMBER POWERS: Separate issue, not

because the number of uncertainties, but the magnitudes of those.

MR. MACHIELS: Yes. And you have to average it -

MEMBER POWERS: I could have one uncertainty, and it was very large, that dominates everything.

MR. MACHIELS: Of course. But what I'm saying is that more species you introduce, basically, you accumulate more uncertainties. And then you can basically come up with a fairly large number that way.

The easiest way, obviously, to do that, as I explained earlier, was first of all, to refer to the fresh fuel assumptions. I mean if you can live with it, that was the penalty associated with living with a fresh fuel small assumption, it was small enough, simplification basically was justifiable.

But as explained, we are no longer in that situation. First of all, we are working with much higher enrichment. And that means that if you keep the fresh fuel assumptions, you end up with a low capacity storage and transportation systems.

And more systems means more operations, increased costs. If you need more systems, that results usually in the higher dose. And when you talk

about transportation, if you talk about low capacity system, that means you will have a lot more shipments involved.

And that means that you have to include also, the non-radiological risk, which you have the classical accidents on the road, which tend to dominate clearly over the radiological one.

MEMBER BROWN: What do you mean by a lot more shipments, just calibration, is that twice as many?

MR. MACHIELS: For PWR, the classic example, instead of having a cask which contains 24 PWR sound base would be something that contains 32. So in the same envelope, in the same volume, you can fit 32 PWR instead of 24. And so you reduce your shipment by a factor of one-third probably.

MEMBER BROWN: Okay, thank you.

MR. MACHIELS: So burnup credit then was introduced and accepted. And it's basically trying to get upgraded for the reduced reactivity of the spent fuel compared to fresh fuel. And as you've heard, it comes in several flavors.

Actinide only, where basically you focus on the major actinides. And then the next step is the actinide was a subset of fission products, and

including some minor actinides, which is what was much talked about in the context of this Rev. 3.

And then there is the full burnup credit, where you leave nothing on the table there. You take credit for everything. But then it requires maybe a different approach.

In the transportation area we have followed the classic safety criticality method, which is using individual components in the shipment and associating uncertainties with those.

When you go to full burnup credits, then a different approach is required. And full burnup credit has been used, for example, in the management of spent fuel pools of the reactors.

So we did some work some five years ago in terms of assigning a probability of a critical event during transportation. And as you know, that relies on a number of activities which are going to happen at the power plant.

And we took, as a reference, we worked with a power plant which is located very close to where our contractor is located, which is in Southern California. And we basically follow the plant procedures of that plant.

We started with the very beginning, when

the plants receive fresh fuel and is going to use that fresh fuel to fuel the reactor as well, subsequently following the life of a fuel assemblies throughout it's life until its discharge.

And obviously, during that time there is activities which are tracking and recording the burnup by fuel assembly seal numbers. Then we talk about now the operation involved in loading a cask. And that involves a number of operations. And finally, there is a number of verifications when it is time to ship that fuel.

So all those activities -- excuse me -- all those activities, the last two, are happening on the plant. I'm going to focus on those two activities here.

This is basically what's happening on the plant when you talk about loading a cask. You select fuel assemblies which are in compliance with the certificate of compliance.

You prepare a fuel movement sequence sheet for loading your cask. There is some verification involved. Then you have the actual transfer of the fuel assembly from the pool to the cask. There is some verification involved.

And then if you have, this is something

which is not universally applied, but you can do a video of all the operation. And you have a way to independently verify what has happened before.

And then before shipping, you can also do some independent verification in terms of relating the records back to information which was in the core management systems.

And so in all those sequence here, you basically have a potential, obviously, for error of commissions. And what we are trying to capture that, the main thing that I want to emphasize in this is that when we talk about misload here, we are talking about misload assemblies during shipment, which is different from what we have talked in the context of the previous discussion.

Because obviously, in the context of what we discussed, the 10^{-2}, this is a very high number obviously. But there were a number of activities of the power plant that detected that there was actually, the assemblies should not have been in the cask.

And so prior to shipment an assessment would be made whether those assemblies make a difference from a point of view of criticality or not. And in all the cases that we have seen, there would be no inference on the criticality.

On the contrary, in one of them in the Grand Gulf, instead of loading two cycles, they loaded three cycles. So obviously, the criticality would be with having much lower.

So there is, through this process, a number of recovery which is possible. And obviously, what you're trying to quantify is what has escaped, obviously, all the attention and all the verification steps, which are included.

And so from that point of view, when we look at what we assume, based on misloading of reactor operation and base of actual experience, we see about a factor of ten. In the reactor operation we, both the NRC and our study, used basically a study that was performed by AREVA, in terms of reviewing information.

And then we look in reality, it's basically a factor of ten difference. The advantage of a reactor is that as you go up in power, you will notice that if there is an error, this will be noticed by the reactor area.

So what we are trying to capture is obviously a misload which will have escaped all the detection pattern and eventually, will find its way when it is being shipped.

And from that point of view, the largest

probability that we see is at the very bottom line here, is that when throughout the life of the fuel assembly, since the receipt until the discharge, there has been basically a disconnect between the fuel assembly and its record.

And this, the only way to recover from that is really at the very end here. And if you don't do that systematic verification, it will go through. If you do that systematic verification you have a good chance to catch it.

And so from that point of view, depending on the exact procedure applied at the plant, you will see those probabilities obviously being modified on that. But this is what we did.

Now this is what is happening at the plant here, the blue, the highlighted area in blue. Obviously, there will be other things, obviously, now there will be what is a probability of an accident during the transport itself, assuming a nominal mileage.

And this assumes that it's transportation by railroad. So there is an extensive database from the Federal Railroad Administration, which gives you all kinds of data in terms of probability of derailments. And it talks about the passenger car,

freight car, hazmat cars, and so on.

And you can, more or less, define to some extent the probability they're going to pick because you basically have, for example, the flexibility of limiting the speed of the train, for example, that will influence the probability of derailment.

The next step, obviously, is that if you have an accident and include that probability, then is the accident severe enough, and what is the probability of having an accident which is severe enough that you actually punch some kind of a defect into the cask. And at the same time, there is presence of water. So that basically now, you are getting to introducing mud or water into your gas.

And so when you assume, when you multiply all those probabilities together, you typically get a very low number, which is of the area 10^{-16} per shipment. Obviously, we will do more than one shipment, but per shipment it's a very low probability. And the result of it is that accident during transport is a very low number to start with.

MEMBER STETKAR: Albert?

MR. MACHIELS: Yes?

MEMBER STETKAR: What's the likelihood of that train being hit by a meteorite? I know what it

is. It might be right about the size of a bowling ball, traveling at 15 kilometers per second.

MR. MACHIELS: I have no idea.

MEMBER STETKAR: It's probably about nine orders of magnitude, at least, higher than that little number that you have calculated there. So what confidence do I have in this number?

MR. MACHIELS: I think that if you look at 16, you should not have any confidence in that number.

MEMBER STETKAR: Okay. How about ten orders of magnitude higher than that, that -

MR. MACHIELS: Oh, yes.

MEMBER STETKAR: -- your uncertainty might be a factor of oh, 100 billion.

MR. MACHIELS: No, if I work with a note of confidence, I would be thinking about the property of the order of three orders magnitude, you know, between -

MEMBER STETKAR: Oh, so it might be as high as 10^{-13}?

MR. MACHIELS: Yes.

MEMBER STETKAR: Which is six orders of magnitude smaller than being hit by a meteorite?

MR. MACHIELS: Yes.

MEMBER STETKAR: So how do I interpret

this silly little number?

MR. MACHIELS: Well, essentially with a -

MEMBER STETKAR: That's a small number.

CHAIRMAN ARMIJO: I don't know about the silly part.

MEMBER STETKAR: Well, it's a silly small number.

MR. MACHIELS: That means that -

MEMBER POWERS: Yes, I mean that's the whole point. We're trying to reduce uncertainties and these numbers up here, they're in their single uncertainty up there. And the uncertainties are huge.

MEMBER STETKAR: Much huger than three orders of magnitude.

MEMBER POWERS: Yes.

MR. MACHIELS: You really have to look at it, well, handling first of all with the material which doesn't go critical very easily. It's spent fuel and so from that point of view it takes work to make it critical. And at the same time, then you have a number of steps which make the fuel very -

CHAIRMAN ARMIJO: If you just specified that this was a spent fuel cask, loaded the way we load them and you just filled it with water, you know, can it go critical.

MR. MACHIELS: No.

CHAIRMAN ARMIJO: The answer is no.

MR. MACHIELS: Let me give you -

CHAIRMAN ARMIJO: If all this other stuff -

MR. MACHIELS: -- a typical example, but not example, but a true story. I went to Idaho once with an NRC guy. And we were looking at a project basically to look at a cask going critical, spent fuel cask critical.

And during the discussion then, it came about that the INL guide said that if we want to have something become critical, you will have to push some fresh fuel. So without putting a lot more criticality, and without putting a lot of misloading, those basically are essentially not going to be critical.

CHAIRMAN ARMIJO: But you really don't have to go through all these intermediate steps, where everybody can get all upset, to come to the conclusion that if you follow this ISG, and you just simply fill a cask with water, you're still in good shape.

MR. MACHIELS: That's not because you don't put some fresh fuel in it.

CHAIRMAN ARMIJO: That's what I say,

follow the ISG, don't put fresh fuel in the cask.

MEMBER POWERS: So what you're saying is the total uncertainty here is the probability that you put some fresh fuel in there, which, as a rough estimate, 10^{-3}, because it's a human error. So it's not 10^{-16}, it's 10^{-3}.

MR. MACHIELS: No, but you would never ship something with a fresh unit. Even if the incredible -

MEMBER POWERS: If I was dumb enough to put some fresh fuel in it, I'm dumb enough to ship it.

MR. MACHIELS: Okay.

CHAIRMAN ARMIJO: But then you know what the problem you have to address, right? Don't ship fresh fuel. Put fresh fuel in a spent fuel cask.

MEMBER POWERS: I already know that. I didn't need to do this analysis not to do that.

CHAIRMAN ARMIJO: Exactly. But we're in agreement, so that that's where you focus your administrative controls.

MEMBER RYAN: This is an interesting calculational exercise and all. But I tend to agree that if there are probabilities of errors that could really cause a problem, to be, let's see, 13 orders of magnitude higher than this, we're done with that. And

let's focus on managing the risks where there is a higher probability of something going wrong.

CHAIRMAN ARMIJO: Yes.

MEMBER RYAN: So we're done with that part is what you're saying -

MR. MACHIELS: Can I move on?

CHAIRMAN ARMIJO: Yes.

MR. MACHIELS: Okay. All right so coming -

MEMBER RYAN: And finishing up fairly quickly -

MR. MACHIELS: Yes, right.

MEMBER RYAN: -- for the next speaker.

MR. MACHIELS: Coming back to burnup credit validation now, we have developed an alternative approach which is based on inner reactor measurements, those are basically required as part of running a power plant.

It was a cooperative effort involving Duke Energy, Studsvik Scandpower, and Dr. Dale Lancaster was here. The principle investigator was Professor Kord Smith. What we did is we looked at the four reactors, about 44 cycles of reactors. And about over, close to 700 of those flux map is to present the core of a PWR.

And we are looking at roughly a million measurements of miniature efficient chambers which are inserted in the central part of an assembly to basically measure the flux distribution throughout the core.

And basically, when you have a reactor, it contains, at the beginning of a cycle, from fresh fuel to something which has been once burned, to at the end of the cycle, something which is basically once burned to discharge. So you have a range of burnup in the reactor from about zero to something, which is close to your discharge burnup.

And by looking at that information and extracting the information which is available from that, you basically come up with a number of benchmark here. And what you get is basically the definition of 13 different benchmark which is based on those measurements.

And if you take an example, this is like a standard problem. You look at something which is described in details in term of geometry correctness and so on. And then basically the benchmark calculates that if you start from fresh, going to burnup, to ten, 20, 30, 40, 50 and so on, it will give you basically what your code is supposed to calculate

in terms of depletion in reactivity.

And that gives you basically the benchmark, which allows to use your tools in order to verify whether you have systematic bias as a function of burnup of some other statistics.

And this is an example of the differences that, when you look at the draft, ISG-8, Rev. 3, and you look at the end response of depletion benchmark, you see, just for a point of view on uncertainty, when you look at the discharge burnup, 40 to 50, there is about a difference of three in the uncertainty, which is lower for the end response on methodology.

And on top of that you get more credit using that approach because you don't disregard any nuclides. You basically take everything which is included in the spent fuel.

The difference is fairly easy to explain. The reactor measurements are highly accurate measurements. While the value, which are basically in the draft ISG, on which you rely on basic chemical assay, that the uncertainties associated with a chemical assay is much larger, that is really the simple reason for that.

So in summary, I just presented very briefly, an alternate approach. I think that it's

reactor-based, based on the operation. It's applicable to any application, storage, transportation or disposal.

And the beauty of it is that it's a normal sequencing from reactor operation. We seem to have a disconnect sometimes, when we talk about storage and transportation compared to the reactor operation.

We seem of suffering from amnesia, that certainly all the careful work that we do in terms of running our reactor, and power distribution, and so on, suddenly now, once we talk about storage and transportation, this is an entirely new animal.

And from a mutated point of view, there is certainly an interest in basically having continuity in handling the information which is coming from the reactors.

And for transportation burnup credits is a higher priority topic, as mentioned increased capacity, loading a greater percentage of the spent fuel population. And as we see in basically in terms of the potential for critical event during transportation. This is a very low probability event which basically is essentially zero.

And so from that point of view, removal of conservatism result in improvement in safety by

balancing criticality risk and operation of risk. This is something which is coded here.

And I will certainly say that ISG, Rev. 3 is not only an example of extreme conservatism, I think it has been moved in the right direction. But any improvement that we can do has some potential benefit from a risk point of view. Because as I mentioned, we have balancing, radiological risks, which are such nonexistent, with some more real risks which are, with the transportation which are.

None radiological which are, this is the one we experience every day when we are under worked. Thank you.

MEMBER RYAN: Thank you very much.

CHAIRMAN ARMIJO: Just one quick question, just assuming that you could use the depletion benchmark-type approach, the reactor approach.

MR. MACHIELS: Yes.

CHAIRMAN ARMIJO: What would it do as far as cask capacity?

MR. MACHIELS: Well, it will change, you are limited by the volume, okay. So when you go to 32, that's all you can put is 32. But what you increase is the percentage of the population which is in storage, into a cask. So that means -

CHAIRMAN ARMIJO: Why not a lower burnup fuel into the cask?

MR. MACHIELS: Yes, right, yes. You see the different curve that we are showing by the NRC staff, you basically lower the curve. So you are able to put a greater percentage of the existing inventory into a cask.

MEMBER SCHULTZ: Albert, to that point again, on your last slide, the slide previous to this, the difference that you've shown here for the 32 versus 24. That's not the difference between full burnup credit in the ISG-8.

MR. MACHIELS: No, that's right, yes. The ISG-8 should allow you to load the 32 casks.

MEMBER SCHULTZ: That's the point I wanted to hear.

MR. MACHIELS: The main difference is basically the percentage of the population which would be in place.

MEMBER SCHULTZ: So it would be more important, if the industry goes forward with loading more assemblies from the spent fuel pools to casks, it could become more and more complicated to load full casks.

MR. MACHIELS: Right, yes.

MEMBER SCHULTZ: And we may need to take credit for full burnup then.

MR. MACHIELS: It would be a percentage of the population which is higher, that would not be going full capacity in the casks, no.

MEMBER SCHULTZ: Thank you.

MEMBER RYAN: Thanks again. One more speaker, are you ready, Mark?

CHAIRMAN ARMIJO: I guess I'm still missing the benefit. If that's the cask capacity, what's the benefit of being able to use your approach?

MR. MACHIELS: The difference is that there will be, the more conservative you become basically, the tail of the assembly is to kind of put in a cask increase. So those casks will not be able to take full benefits of the capacity of the cask. Because you will not be able to justify that they will not go critical.

CHAIRMAN ARMIJO: But you would still be limited by heat.

MR. MACHIELS: No, heat is a different -

MEMBER SCHULTZ: Sam, it's more likely to be those assemblies that were discharged a long time ago at low burnup.

CHAIRMAN ARMIJO: Ah, got it. Okay,

thanks.

MEMBER RYAN: Marc?

MR. NICHOL: Yes, morning. Welcome and thank you for allowing me to speak. I'm Marc Nichol from Nuclear Energy Institute. I appreciate the opportunity to provide industry's perspective on the draft ISG-8, Revision 3.

I'll go through here rather quickly. I do want to voice our general feedback on the guidance, that it's an overall improvement over Revision 2. We believe this will gain greater utilization of burnup credit in transportation and in storage.

One of the points that wasn't made prior to this, but there is a different approach in criticality analyses between the storage cask and the transportation cask, even for ones that are dual licensed for both storage and transportation.

Storage relies heavily on soluble boron in the pool. Transportation, sometimes, maybe often, will still use the fresh fuel assumptions. That can result in different allowable contents between the storage and transportation. So this helps bring those two worlds together.

We did have a few suggestions for improvements, five categories in total. The one I

would like to speak a little bit more about today is burnup verification. Although, there were a couple others.

One of our major points on burnup verification is that if the guidance or user is going to develop strategies to prevent or mitigate misloads, that the root cause for misloads needs to be identified and well understood. That way you can make sure that the mitigating strategies are effective.

In this area we identified three major categories for potential misloads. Each of these might have some subcategories. The ones we typically think of is loading the wrong fuel assembly. You meant to load assembly X, you obviously loaded assembly Y.

The other two, one is calculating a burnup higher than actual. This would typically be an error in calculation, something like that. Or the one that we heard earlier is more likely, is assigning the wrong burnup value. And this would happen earlier in your planning stages. So we think that identifying these is important to evaluate the effectiveness of the strategies.

MEMBER RYAN: So just to be clear, Marc, number three is the most important one in your mind?

MR. NICHOL: That's correct. Number three is the one that leads to the 10^{-2} probability that we've heard today. So that is the one that would be the most important to address.

And in that respect, we evaluated in-pool burnup measurements as not being very effective at accomplishing these. Because its ability to prevent the misload is very limited. While it can provide a burnup value, it's typically not very accurate.

In fact, reactor records are much more accurate. While it could confirm that your burnup is higher than what would be allowed in that cell, there would still need to be administrative controls around that. And, of course, taking the burnup measurement is problematic, difficult to do.

So we believe that there are other more effective means to doing that. We've recommended, and it's the alternative presented in the ISG-8, is a combination method doing two things.

One, attempt to preclude the misload from occurring. And two, if a misload occurs, ensure that it remains subcritical. So you're covered in both areas. We identified this as being defense and depth.

To preclude a misload from happening, this would fall on administrative controls. And we believe

focusing on well accepted QA practices is appropriate, learning from other areas such as loading of the cores is very important.

And because it has a defined role as precluding the misload, the administrative control should focus on that function. The administrative controls are not very effective at mitigating the consequences, and so to make sure that the administrative controls are properly aligned with their intended function.

And, of course, they can be improved over time if you have some OE. And certainly industry agrees that 10^{-2} is not an acceptable number for misloads. So there is plenty of OE out there for us to learn from.

The second, ensuring that if a misload occurs it remains subcritical. This is the by-design type of approach that I referred to before. And this is through your misload analyses. We believe that one, if you evaluate the misloads and can confirm that, if you have that credible misload, that it is subcritical by design, then it's inherently safe that way.

But it depends on a couple of factors. One, you have to use appropriate assumptions and

certainly those need to be developed considering what fuel you might have in your pool.

The second is that we believe it's important to keep these administratively simple. If the misload analyses are quite complex, you could add additional complexity into the administrative control of that. And that's exactly where we want to reduce complexity. So we think we need to keep it simple. Thank you for your time.

MEMBER RYAN: Thanks very much, Marc. Any questions or comments?

MEMBER SCHULTZ: I have a question, Marc. It would seem that item one is, to the industry, would be much more, and to the regulator, much more important than item two. Item two, we've talked about a number of features of the Guidance that's being provided, that would assure that that would be the case if there were a misload.

Based on what we've heard, and what the OE is here, it seems like most the experiences associated with an administrative issue associated with a disconnect between what should have been the paperwork for the assembly, the calculations associated with the assembly, and the assembly itself. So it's really an administrative feature.

MR. NICHOL: Right.

MEMBER SCHULTZ: And the two features that are being emphasized are QA and also, third party check at the right time in the process.

MR. NICHOL: Right.

MEMBER SCHULTZ: So has NEI bought the second set of controls that have been recommended within the guidance?

MR. NICHOL: Not all of them. We, of course, recommended our own list of administrative procedures that should be in the guidance. Now we recognize that industry goes beyond that.

And the reason we recommended a limited subset is we thought it was appropriate that industry goes beyond what's generally in the Guidance. And much of industry, if not all, does do an independent third party check.

MEMBER POWERS: But the essential point that you make that, as in hardware, administratively simple is inherently safer and complex, I think is an extraordinarily important point to make.

MR. NICHOL: Yes.

MEMBER POWERS: Administrative simplicity, you got check after check after check coming along here, you're just going to get -

MR. NICHOL: Right.

MEMBER POWERS: -- confused on where you are.

MR. NICHOL: And that was part of the basis for our recommendation on the assumptions behind misload analyses. We recognized they were overly conservative. But with the limited time we had, that was the best we could come up with that was a compromise between simplicity and conservatism.

MEMBER SKILLMAN: Thank you.

MEMBER RYAN: Thanks very much. I'm going to return the three minutes that John Stetkar used yesterday. So we're even.

MEMBER STETKAR: It only seemed like yesterday. It was this morning.

MEMBER RYAN: Well, it seemed like yesterday.

CHAIRMAN ARMIJO: Okay, you're ahead of schedule, Mr. Ryan. Well, look, I think first of all, I would like to thank the presenters, the staff, and the EPRI, and the industry. I think an excellent piece of work. That from my opinion, it's really nice work putting this together, a lot of progress.

I don't know if other members want to make any additional comments. But I thought it was really

enlightening and on the right track. So with that --

MEMBER RYAN: Yes, I'd like to second that. I think the staff has done a nice job. And I particularly appreciate the fact that they collaborated and coordinated with industry on this effort.

So it's a true effort across all lines. So I really appreciate the fact that everybody has put a lot of work into it. Thank you.

CHAIRMAN ARMIJO: And we're really right on schedule. So what we're going to do is take a break for lunch. And we'll reconvene at 1:15.

MEMBER RYAN: Done.

(Whereupon, the meeting in the foregoing matter went off the record at 12:11 p.m. and went back on the record at 1:13 p.m.)

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

(1:13 p.m.)

CHAIR ARMIJO: Good afternoon, we're ready to reconvene and our next briefing will be lead by Mr. John Stetkar, John.

MEMBER STETKAR: Thank you, Mr. Chairman. For the benefit of the members we're going to be hearing presentations on US-APWR Design Certification Chapter 9 and the Comanche Peak Combined License Chapters 5, 8, 10, 11 and 12.

And the reason we're doing this is in preparation for an interim letter from the Committee, on progress on both the Design Certification and Combined License application. As we've been doing periodically, to let both the staff and the applicant know if we have any particular areas of concern, primarily to give them a little bit of forewarning and also to make sure the Commission knows that we're still carrying on with this effort.

And we have quite a bit of material to cover today, as I said it's both Design Certification and Combined License. Jeff, do you want to say something?

MR. CIOCCO: Yes, thank you. My name is Jeff Ciocco, I'm the lead project manager for the US-

APWR Design Certification Licensing review. Thank you to the Full Committee for having us here today to present Chapter 9, the auxiliary systems.

Along with myself representing NRC staff, we have a lot of our technical staff in the audience here to answer questions that you may have and I'll be giving a brief presentation on Chapter 9, kind of a high level overview following Mitsubishi's presentation. Thank you.

MEMBER STETKAR: Thank you very much, and we'll turn it over to Jim, I don't who, up front, Kevin?

MR. LYNN: Good afternoon, my name is Kevin Lynn, I'm the Licensing Engineer for Chapter 9 of the DCD. And today we are here representing MHI, Mitsubishi Heavy Industries. And we'll be discussing Chapter 9, which is the auxiliary systems.

So as I said, my name is Kevin Lynn, and seated with me here is Hiroki Nishio of MHI and Dr. James Curry, will be assisting me. And we also have technical experts in the crowd to answer any questions as necessary. So I'll start with a general introduction.

The US-APWR DCD was submitted by MHI in December of 2007. Chapter 9, we're discussing today

in particular, is about the auxiliary systems. And Chapter 9 was previously presented to the US-APWR, ACRS subcommittee on March 22 and 23 of this year.

The basic design concept of the US-APWR is very similar to a conventual four-loop plant. There are some unique and specific features of the US-APWR that are relevant to Chapter 9, and those are the ones that we will mainly be discussing and summarizing today.

This is a general outline of Chapter 9 of the DCD. It's divided into five major sections, fuel storage and handling, water systems, process auxiliaries, air conditioning, heating, cooling and ventilation systems and other auxiliary systems.

And for each of these five major sections, it goes through the systems that make-up that and they're all listed here. I won't go through each of them, but they all follow the SRP and so they're similar to what you've been use to seeing in other designs.

The spent fuel pit or the SFP, is described in the Section 9.1 of the DCD. During our previous meeting in March with the ACRS, we received several questions about the SFP and so we want to provide a little bit of a followup on those today.

One of the questions we were asked about is about the SFP lines, which are safety related and the RWSP clean up system, which is non-safety and how those are separated from each other. Another question was about the, if cooling of the spent fuel pool was lost, how long would it take to start boiling, if you started at a hypothetical lower lever or minimum level of the weir gate.

So we have, this slide says that we will provide a response, but this is actually been updated and MHI has now officially submitted a response to those two questions to the NRC recently. So the NRC and ACRS will have those formal written responses to be able to review.

MEMBER STETKAR: Okay wait. By the way, we seldom say nice things about people. We've had very good experience with MHI and MNES throughout our efforts. They've been very, very responsive.

Anytime we've asked comments, we get either oral responses in a timely fashion during the meetings or, in this case, written responses and we really do appreciate that, so I wanted to thank you for the, hope we keep that kind of exchange going in the future.

MR. LYNN: Well thank you. These two

1 particular questions, we reviewed the previous meeting
2 with the transcript and all the other questions during
3 the meeting, we either provided an oral response
4 during the meeting and these particular two we took as
5 actions to follow up. So we've now submitted those
6 written responses.
7 MEMBER STETKAR: Thank you.
8 MEMBER POWERS: You realize of course
9 we've exhausted your quota with him and --
10 CHAIR ARMIJO: And that's the last
11 compliment you'll get.
12 MEMBER STETKAR: That's right, you got the
13 one.
14 MR. LYNN: Hopefully this is on the
15 biggest topic.
16 MEMBER STETKAR: We're about half way
17 through, I thought that was about the right time.
18 MR. LYNN: We also received some questions
19 about the SFP as it related to Fukushima issues. And
20 at the time there was some discussion about when the
21 Fukushima related issues would be discussed.
22 And as part of an RAI we received from the
23 NRC, MHI has committed to make a technical report to
24 address the Fukushima topic as a whole and that
25 technical report will be submitted in February of next

year, at the end of the month. And in that we have you know, made sure that the SFP related issues are part of that, are part of the scope of that. So those will be addressed at that time.

MEMBER STETKAR: Jeff, we'll see that as, in the next phase of the re-do?

MR. CIOCCO: Yes, that's correct.

MEMBER STETKAR: Okay, thanks.

MR. LYNN: Next we'll talk about the component cooling water system, which is discussed in Section 9.2. The CCW system for the US-APWR is a four-train system. And each train consists of one pump, CCW pump and one CCW heat exchanger.

The four trains are separated into two subsystems as shown in this figure here. Where each subsystem has a CCW surge tank and each surge tank is divided into two, with an internal partition plate.

The CCW supplies water to safety components as well as non-safety components. The connections are the supply headers to the non-safety components can be automatically isolated on ESF signals.

MEMBER SKILLMAN: Is each pair independent subsystems, 100 percent capability? Are these four 50 percentors or four 25 percentors?

MR. NISHIO: Fifty percent.

MEMBER SKILLMAN: Four 50 percent, okay thank you. Thank you.

MEMBER STETKAR: Kevin, you said that the, I think I misheard you or miss-remembered something, that the supplies to the non-safety loads are isolated automatically? I thought that, we had some discussion about automatic and manual isolation of --

MR. LYNN: I believe the discussion you're referring to is the separation between the trains, which is the safety related portion. And that there was discussion about whether or not that was automatic or manual.

But the connection between the safety and non-safety side, because those are non-safety components, that isolation is done manually. Because in an accidental scenario, those components do not need TWF.

MEMBER STETKAR: How do you classify the cooling water through this spent fuel pit heat exchanger and the reactor coolant pumps and the charging pumps? Those are not isolated automatically, or are they?

MR. LYNN: No the, well the charging pumps would be a non-safety component because MHI does not,

the US-APWR design does not need them --

MEMBER STETKAR: That's correct.

MR. LYNN: -- during an accident scenario. But the water, the cooling water to the RCP thermal barriers is necessary to prevent an RCP seal LOCA.

MEMBER STETKAR: Okay this is getting a bit detailed for a Full Committee meeting, but I think we're okay on time. I thought that we saw in Interim Rev 4, of the DCD, that the line, the cross tie valves that are motor operated valves?

MR. LYNN: These valves?

MEMBER STETKAR: Those two. Do not receive automatic isolation signals, is that correct?

MR. LYNN: That is correct in Interim Rev 4.

MEMBER STETKAR: In Interim Rev 4. In Rev 3 they did?

MR. LYNN: Yes.

MEMBER STETKAR: Okay. And that line supplies one set of non-safety related, that vertical line there between those valves, supplies safety related, safety grade equipments as you call it, and non-safety components. One partial header indeed has automatic isolation signals, those air-operated valves.

MR. LYNN: These two, yes.

MEMBER STETKAR: The other part of the header I thought supplies the charging pump, the reactor coolant pump coolers and the spent fuel pit cooler or at least my recollection was --

MR. LYNN: Yes, gated here in this box, this would be like the RCP thermal barriers and the SFP components.

MEMBER STETKAR: Okay. And those are not isolated automatically?

MR. LYNN: No. The automatic isolation is this right here, which goes to the charging pumps.

MEMBER STETKAR: The reason I bring that up, for information for the other committee members who weren't there is I believe MHI has done an analysis to show that under certain design basis accidents, assuming a single failure of loss of AC power coincident with the accident.

That leaving that line open still provides 50 percent, at least two 50 percent trains, depending on how you do all of the combinatorics. However I think that in the subcommittee meeting we discussed possible other scenarios.

For example, if you have a loss of power after safety related valves open up on, let's call it

train B, you can leave one pump supplying both trains of safety related equipment and what you're calling here, safety grade loads. And it wasn't clear whether the flow from that pump, or the heat removal from the heat exchanger that's associated with that pump, actually has enough capacity to remove that amount of heat.

So that in a sense, that kind of configuration, assuming a different timing of your single failure, might leave you vulnerable?

MR. LYNN: Yes. And we remember that discussion, and after that ACRS meeting the NRC actually asked that as a formal RAI to us, as a followup to your question, so they postulated the same scenario. We answered that RAI, we responded recently.

MEMBER STETKAR: Okay.

MR. LYNN: And the staff reviewed our response and they had some additional followup questions and clarifications that were currently in the process --

MEMBER STETKAR: Okay, but that's in the formal RAI process right now?

MR. LYNN: Yes.

MEMBER STETKAR: Good, thanks. That

helps.

MR. LYNN: The essential service water system is also discussed in Section 9.2 and the ESW system is separated into four trains, where each train has its own pump and this is a simplified schematic showing it. But each train provides cooling water to the CCW heat exchanger that was discussed, shown on the previous slide. So this heat exchanger.

As you may know, the US-APWR uses gas serving generators, or GTGs, instead of diesel generators. This one notable difference. The GTGs themselves are described in Chapter 8 of the DCD and that has already gone to the ACRS.

But Section 9.5 of the DCD describes the support systems for the GTGs, so it is somewhat relevant to this meeting here. This right here, I list the support systems that the GTG uses.

One notable difference between GTGs and diesel is that the GTGs are air cooled and so therefore there's no cooling water system, so that section of the DCD, or that subsection, is omitted because it's not applicable for the, our design.

MEMBER SKILLMAN: How is the lubrication cooled, please?

MR. LYNN: How is the lubrication cooled?

Yes, I'll differ to one of the experts on the GTG system for this question.

MR. TANAKA: This is Hiroki Tanaka, MNES. Lubrication is also cooled by air.

MEMBER SKILLMAN: Thank you. Okay.

MR. LYNN: So now I'd like to discuss the resolution of open items from the safety evaluation report. The SER from the NRC was issued in February of this year, just prior to the ACRS meeting. And that SER identified 20 open items for Chapter 9.

Since the ACRS meeting we've been working with the staff to try and resolve those open items. And as of now we have resolved 12 of the 20 open items. There are eight open items that are still in progress, but of those eight there's no, MHI believes there's no significant issues.

In some cases we've submitted response and the staff is still reviewing it and other cases we're still preparing our response. So we believe there's no significant issues and I think the staff's presentation will address some of the specific open items remaining.

MEMBER STETKAR: Thank you. Members have any other questions or comments for MHI and MNES? If not, thank you very much. As usual very efficient.

This is, Chapter 9 is one of those chapters that covers a lot of systems and in some designs raises a lot of questions. Not so many this time.

(Off the record comments)

MR. CIOCCO: Shall I begin?

MEMBER STETKAR: Yes.

MR. CIOCCO: Thank you. My name is Jeff Ciocco, I'm the lead project manager for the US-APWR Design Certification.

I'll go through just a couple of high-level slides here for Chapter 9. As MHI stated there's very few issues remaining on Chapter 9. So I'm just going to kind of give you the overall licensing review of where we're at for the overall design certification and then just touch on a couple of the open items that we presented at the subcommittee meeting.

What this slide has is the six phases of our six phases of our Design Certification Licensing Review. This is our publicly available schedule through the six phases and through the rulemaking. Phase 1 is completed.

We're currently progressing through Phases 2, 3 and 4 simultaneously. In Phase 2, as the ACRS knows, we've completed ten chapters. Of those ten,

eight have been through the subcommittee and the Full Committee and there was letter generated September 22nd of 2011 on those eight chapters. That's Chapters 2, 5, 8, 10, 11, 12, 13 and 16.

The two other chapters that we've issued to the ACRS are Chapter 15, we presented that a couple of months ago to the subcommittee. And Chapter 9 we're here today to present to the Full Committee.

The critical path item right now is Phase 2 is the Seismic and Structural Analysis, Sections 3.7 and 3.8. As you can see, same as MHI talked about, these are the sections in Chapter 9, Sections 9.1 through 9.5, the fuel storage and handling systems. The water systems. The process systems, air conditioning, heating in the main control room, as well as other systems, the GTG and fire protection systems.

So whenever the staff was here back in March we presented the overall 20 open items where they were in the particular sections. And then we presented five that we thought were particularly challenging at the time. We've come to resolution on most of these open items. And I'll just kind of run through them today where we're at currently. Not in the SE that you have, but as we work through these in

Phase 4.

The first one is the essential service water. It's now a confirmatory item and we are just waiting a change to the DCD in Rev 4, which we expect next year. And this one had to do about a boundary valve between the safety related and non-safety related systems. MHI provided us the necessary design information. And we just need to see that in Rev 4 of the DCD.

Next was an RAI in the component cooling water, which there was a brief discussion about. I think this is a different RAI.

MEMBER STETKAR: This is a different one.

MR. CIOCCO: Yes, this is a different one. And this about a postulated piping leaks in the component cooling water system which could drain the CCW surge tank. MHI showed us that they've met the Regs and there's a particular Branch Technical Position 3-4, which was met and MHI has agreed to add explanation to the Rev 4 of the DCD. So we've already seen the markups and we're just waiting now, it is confirmatory until we see the next change in Rev 4 of the DCD.

The next open item is in the Condensate Storage Facilities, this is Section 9.26. This is

also a confirmatory item that the response is acceptable. And this was about a dike surrounding the condensate storage tank and how they applied GDC 2 and GDC 60. MHI showed that the CST, that the particular issue here was non-safety related. They've modified their CST description in the DCD and it's now a confirmatory item in Rev 4 of the DCD.

And the last two that we have are in the main control room area ventilation. And these are still open items at this time. The first one is about the underlying issue about the reliability of AAC, the alternate AC gas turbine generator. And we actually just received MHI's response on this issue on August 2nd, so it's currently under staff review. So we may be nearing resolution on this one soon.

And then the last RAI that we presented back in March is still an open item. We're waiting for MHI's response. This is about the main control room, about the air handling unit cooling coils and whether leaks from the cooling coils can occur. MHI has its draft response and will soon be submitting a final response to the NRC.

So I would agree with MHI that we've made significant progress in Chapter 9 and we're closing up a lot of the confirmatory items and just have a few

open items left in Chapter 9.

MEMBER STETKAR: Jeff, this is, it's a question that we discussed to some extent during the subcommittee meeting. And it's at that interface between Chapter 9 and Chapter 16, it's really more of a Chapter 16 tech spec question.

But we noticed that the essential chilled water system is actively excluded from the technical specifications, which seems a bit strange. Because it is a safety related chilled water system that provides cooling for control room ventilation in addition to several other areas. We kind of raised that question during the subcommittee meeting and we'll probably follow up on Chapter 16 but it is related to Chapter 9.

One of the things that we try to do as a Committee is look across chapters and if we see any systems interaction, or in this case it's systems and administrative controls interactions, try to raise those issues.

MR. CIOCCO: And do recall something, if we had to issue a supplemental RAI on that particular question or not.

MEMBER STETKAR: We had some discussion about it. And as I said it's more of a Chapter 16,

but since it does relate to one of the Chapter 9 systems I thought it might merit at least raising it in this context.

MR. CIOCCO: Yes, does anybody here from the NRC staff know? Larry, do you want to answer it?

MR. WHEELER: I'm sorry. What system was he talking about?

MEMBER STETKAR: Essential chilled water, ECW. It's essential chilled water.

MR. CIOCCO: Yes, I think it was the essential chilled water.

MS. MCKENNA: Good afternoon. This is Eileen McKenna, I'm the Branch Chief in NRO for balance of plant and tech specs. I know we did have this question at the subcommittee. And we did go look actually at a couple of other plants about chilled water systems and whether they were in tech specs or not and we saw a mixed bag. Sometimes yes, sometimes no.

I think our answer with respect to it being a support system that the operability carries over to chilled water I think still stands. But certainly the Committee can apply whatever it chooses.

MEMBER STETKAR: That's, I believe, the response that we had in the subcommittee meeting. And

I think our observation was that there are a number of other support systems, essential service water, component cooling water, ventilation systems, AC/DC power, that are explicitly noted in the tech specs that, as an ex-operator, I hated the technical specifications because they were something that I had to live with much more than I really thought I needed to.

But I had to live with them. And it was nice to go to a document where I didn't need to make some sort of extrapolation or interpolation. It was nice to know that if something was in there I really needed to follow those rules. And if it wasn't there there was probably some reason why it wasn't there. Thanks, Eileen, that helps.

Any other questions for the staff on Chapter 9? Got off easy, Jeff. Thank you very much.

MR. CIOCCO: I did. Thank you. You're welcome.

MEMBER STETKAR: Now what we'll do is have the COL applicant, Luminant, for Comanche Peak come up and talk about Chapters 5, 8, 10, 11 and 12. And, Stephen, you want to give an introduction? I'll turn it over to Stephen Monarque from the staff who's the lead.

MR. MONARQUE: Thank you. My name is Stephen Monarque, I'm the lead project manager for the staff's review of the Comanche Peak COL Application. I want to thank the Committee members for giving us the opportunity to present the Comanche Peak safety evaluation chapters with open items today before the Full Committee.

This is the first time we will be presenting the safety evaluations before the Full Committee. And today I'll be presenting Chapters 5, 8, 10, 11 and 12. And with that I'll go ahead and turn it over to Luminant.

MEMBER STETKAR: Thank you. Don, as soon as you get set up it's all yours.

(Off the microphone comments.)

MR. WOODLAN: Are you ready?

MEMBER STETKAR: Don, we're ready.

MR. WOODLAN: Okay. My name is Don Woodlan, I'm the licensing manager for the Luminant NuBuild Project. It's a pleasure to be here today. The presentation today is going to be made by John Conly. He's our COLA Licensing manager. And we do have a group of technical people in the audience to back up the licensing staff. John.

MR. CONLY: Thank you, Don. Luminant

appreciates this opportunity to discuss Comanche Peak Units 3 and 4 Combined License Application, Chapters, 5, 8, 10, 11 and 12. We thank you for your time.

The agenda includes an introduction and a brief discussion of the topics that were addressed during the subcommittee meetings.

The Comanche Peak R-COLA uses the incorporated by reference methodology that you're all familiar with. FSAR Chapters 5, 8, 10, 11 and 12 take no departures from the US-APWR DCD. There are no contentions pending before ASLV. There is only one outstanding issue in the SER Chapter 8 regarding GDC-5.

During the subcommittee meetings we had far ranging discussions, as was indicated earlier with the Chapter 9 discussions. These were some of the topics, questions that were discussed during the meetings. We had no open items from the ACRS to Luminant. And as you can see here we covered quite a bit of information during those subcommittee meetings.

MEMBER STETKAR: John, we're wonderfully ahead of schedule on time here, which is bad for you.

(Laughter)

MEMBER STETKAR: And you have appropriately blanked the screen. This is your first

time in front of the Full Committee, you're doing this well.

Could you remind us what the GDC-5 issue is under Chapter 8?

MR. WOODLAN: It has to do with whether or not GDC-5 actually applies to the offsite power system. Basically what we call the switching station and the grid. And there's been an issue that we're still trying to work out with the staff. Some of the staff feels that it does apply and that we should commit to it.

We feel it does not apply, and are willing to do whatever is necessary, technically, to demonstrate the adequacy of our offsite power. We've already done, for example, an analysis to show that the offsite power system is designed to handle and accident on one unit and safe shutdown on the other unit. But we just feel that GDC-5 doesn't apply and we shouldn't commit to it. We're working on that.

MEMBER STETKAR: Okay, and that's still in progress?

MR. WOODLAN: Still in progress, yes it is.

MEMBER STETKAR: Okay, thank you.

MEMBER POWERS: What are the consequences

if it does?

MR. WOODLAN: Today, probably none. Because we think the questions that we've answered is what today's interpretation is of GDC-5. As a licensing manager I'm always careful not to commit to something that's recorded. Because things could change.

MEMBER POWERS: You don't want the camel's nose under your tent? Is that what you're saying?

MR. WOODLAN: I'm saying interpretations change with time. If it doesn't apply I shouldn't commit to it, I shouldn't subject to that risk.

MEMBER BLEY: Can you summarize at all the arguments why it would not apply? I've just looked at it, because I don't remember them by number.

MR. WOODLAN: Yes, it probably goes back to the definition of important to safety, because those are the key words that are in there. And it's in, really GDC-2, 4 and 5, in our mind, are all tied together and those are the key words that you need to look at. There has been some very clear discussions on GDC-2 and 4 and the staff has finally said those do not apply.

So one of the arguments is all three of those are the same scope, why would one apply and not

the other two when the scope is the same in the GDCs. Yes. Another argument is we actually have GDC-17 as the controlling criterion, and if you look at the wording in there it's different and it doesn't just limit it to important to safety. In fact it has very specific words to address how these support systems that are important to safety, implying that they're not important to safety.

We went back and looked at the operating plants, and I couldn't get them all because you know they took the FSARs out of the public document room. And I don't have the numbers right in front of me. But we found something like 28 of the plants that have multiple nuclear units. And of those 28 that we could find information on, we only found one that committed to GCD-5.

And we also researched a bunch of power upgrades. And all the power upgrades, when they evaluated Chapter 8 and offsite power, they only looked SERs, only looked at GDC-17, they did not even address GDC-5.

MEMBER BLEY: That's interesting, okay. What strikes me that you have to be able to survive the loss of offsite power that that almost meets to GDC-5 by definition. Is that not true?

MR. WOODLAN: Well it's like, I hope I get the right one here --

MEMBER BLEY: We could probably ask the staff this.

MR. WOODLAN: They'll probably be ready to address it. When you look at the other GDC for earthquake for example, we know that the switching yards can't handle an earthquake. So it's only common sense that that GDC would apply. We feel the same way about GDC-5, the grid is not make to fully comply with the literal words in GDC-5.

And what's appropriate, just like we did with respect to earthquake, we didn't just ignore the GDC and the NRC didn't. They did pick out the appropriate parts and said you must comply with this. You must be able to show it can handle extreme weather conditions, high winds, things like that. And we analyzed the grid and the offsite power system and show that we can handle that.

And we feel that GDC-5 should be handled the same way. It shouldn't fully required but the appropriate pieces of GDC-5 should be examined and demonstrate that you can handle it. And for example, that's why we did the review that shows that we can handle an accident and safely shutdown another unit.

So that's how we feel it should work. But, like I say, we're still talking here. We're not at loggerheads yet.

MEMBER STETKAR: Under the first sub-bullet under Chapter 11 we had some discussion. We're settled that that bypass valve is not a Comanche Peak site-specific design feature, is that correct? That that's actually part of the certified design?

MR. CONLY: That is correct.

MEMBER STETKAR: This is, for the benefit of the other members, there's a bypass valve around the radiation monitor and automatic isolation valves from the liquid waste discharge tank, monitor tank, that first appeared in a drawing that we saw for the FSAR, for the site-specific FSAR. And we had some questions about that. And as it turns out it's apparently part of the certified design, it was just not shown on the drawings for that design. But that's the status, right? It is part of the certified design?

MR. CONLY: That is correct.

MEMBER STETKAR: So any questions?

MR. CONLY: As it turns out the valve is very clearly shown on PNID N0EE10156. But that PNID is not duplicated in the DCD.

MEMBER STETKAR: Yes, that's what we heard, that it actually appeared on a detail drawing but somebody left that --

MR. CONLY: It was a level of detail and somebody decided that detail wasn't important.

MEMBER STETKAR: Yes, it's only a little bypass valve. Okay, I just wanted to make sure of that because we had a little bit of discussion about who owned that valve.

MR. CONLY: Are there any other questions on the topics we have discussed with the subcommittee?

MEMBER STETKAR: Any questions? Any members have any? This is pretty straightforward.

CHAIR ARMIJO: I don't remember the issue of flow accelerated corrosion monitoring program, Chapter 10? Trying to remember whether there was an issue or not an issue or something unique here?

MR. CONLY: The discussion was the words high energy systems were used in the FSAR. And the question was does the FAC program apply to all systems. And the answer is yes, we have modified the FSAR to remove the terminology, high energy systems.

CHAIR ARMIJO: Okay, thank you.

MEMBER STETKAR: Anything else, members?

MEMBER POWERS: These guys are no fun at

all are they?

MEMBER STETKAR: They'll get more fun when we get other, these are easy ones. If not, thank you very much. Appreciate it. And we'll ask the staff to come up.

(Off microphone comments.)

MR. MONARQUE: My name is Stephen Monarque, I'm going to be discussing the Safety Evaluation Report with open items for Chapters 5, 8, 10, 11, 12 for Comanche Peak. Slide 2 please.

This is our Comanche Peak COL review schedule. And we've completed Phase 1 and currently right now, as Jeff has discussed, we're in Phases 2 and 3 in parallel.

MEMBER STETKAR: Hold on, Stephen, to avoid laughter in the background we might as well go through and set your slides up.

(Off microphone comments.)

MR. MONARQUE: Thank you. I already went ahead and discussed the title page. And we've already discussed the schedule. This is one that's a summary of Chapters 5, 8, 10, 11 and 12. SER with open items. To date the staff has issued SERs with open items for these chapters. And we presented these chapters in 2011 to the APWR ACRS Subcommittee. We've identified

one significant technical issue, which is Chapter 8, GDC-5, which I'll discuss later.

For Chapter 5. Chapter 5 deals with the integrity of the reactor coolant system pressure boundary, the system reactor vessel, steam generator, reactor coolant pumps. We presented this to the subcommittee in May of 2011. We had one open item that has been resolved. There's no technical issues to be discussed.

CHAIR ARMIJO: There were some materials, pressure boundary materials open items at the time. Are they closed now?

MR. MONARQUE: Yes, the open item related to EPRI water chemistry guideline has been resolved and closed.

CHAIR ARMIJO: Okay.

MR. MONARQUE: For Chapter 8, offsite power/onsite power systems, station blackout was addressed. We presented this to the subcommittee in August of last year. The technical issue we've identified relates to the applicability of GDC-5 as the switching station, will be shared by Units 3 and 4.

Luminant was requested to address how the switching station complies with GDC-5 and explain how

the sharing of the switching station equipment for both units will not impair the ability of equipment to provide offsite power in response to an accident at one unit and an orderly cool down and shutdown of the remaining unit. And the staff's position is that GDC-5 does apply to the Units 3 and 4 switching station.

For Chapter 10. Turbine generator, steam power conversion, feedwater and circulated water systems. We presented this to subcommittee in August of last year. There's no issues to be discussed.

MEMBER STETKAR: And there no --

MR. MONARQUE: No technical issues, no substantial ones identified. For Chapter 11. Liquid/gaseous solid waste management systems. We presented Chapter 11 to the subcommittee in October 2011. We had two open items that have since been resolved, or closed I should say. And we have not identified any significant technical issues.

MEMBER BLEY: Can I take you back to GDC-5 again? I haven't heard the arguments. But as the applicant stated, they feel GDC-17, which applies to electric power systems in particular, for electric power systems, takes the place of GDC-5. And in reading the two I wonder why it doesn't.

GDC-17 integrates the onsite and offsite

electric power systems in showing that you can meet the safety requirement. Where GDC-5 just says any shared system shouldn't degrade the effect. And if you can go through the arguments a little bit we'd appreciate it.

MR. MONARQUE: Okay. Let me turn it over to our tech staff, Tania Martinez. You want to come up here Tonia?

MEMBER BLEY: I didn't go through the details, did you decide that they do meet GDC-17?

MS. MARTINEZ: They do actually. My name is Tania Martinez, I work with the Office of Nuclear Reactor Regulation in Electrical Engineering Branch. They do comply GCD-17. But the fact that they have a sharing the switching station and we looked at the language in GDC-5 we understand that it's applicable. Even beyond the GDC-17 requirements.

MEMBER BLEY: Is this unique to your looking at this plant? Have you required that for other feed unit sites?

MS. MARTINEZ: No, it's not unique. Every single application is evaluated in some merit. In the case of Comanche Peak we're talking about an active plant. It depends on offsite power to feed referred power source that feeds into safety loads. And they

are not the only ones that have been asked the question. There is some precedence and language in other applications that we have looked so far in the operating side of the house.

But as it pertains to Comanche Peak we understand it's applicable because of those sharing of components. All the offsite comes to the plant through that switching station. And actually the applicant has provided enough information for us to thing that they comply with GDC-5. The only point of contention is that they, the applicant, would not like to use that particular language.

But we're still talking to the applicant, trying to figure this one out as it pertains to the compliance with GDC-5 is not resolved yet. But we're in conversations with them.

MEMBER BLEY: But you have accepted that they meet GDC-17?

MS. MARTINEZ: With the supporting information they have provided, which includes analysis, yes.

MEMBER BLEY: Okay. I guess I don't have a safety issue with this then. Okay. Thank you.

MR. MONARQUE: I'll go back to Chapter 12. Thank you, Tania. Okay, for Chapter 12 we presented

this to the subcommittee last year in October. Chapter 12 discusses radiation protection design features, radiation sources, dose assessment and operational radiation program. We did not identify any technical issues to be discussed.

And that concludes my presentation. So if there's any questions from the Full Committee members.

MEMBER STETKAR: Any members have any questions? If not, do we have any members of the public here who would like to make a comment? If not, thank you. And I'd like to thank MHI, Luminant, the staff. Thank you very much for all your preparation. And good presentations.

It obviously went a little more smoothly than otherwise. But it's important to have these types of exchanges to give us an opportunity to get at least updated and briefed on the current status because we do issue these letters.

For the benefit of the staff we'll be issuing to separate letters. We were going to originally bundle these into a single letter. And administratively it just works out easier. So we'll issue one for Chapter 9 for DCD and a separate one for the COL. That's just an administrative issue.

MR. MONARQUE: Thank you.

MEMBER STETKAR: And again, thank you very much. And, Mr. Chairman, I turn it back to you so that we have money in my bank. One hour and eight minutes early.

CHAIR ARMIJO: Thank you, John. Just a second, before anybody leaves.

(Off microphone discussion.)

CHAIR ARMIJO: All right. So this is what we're going to try and do, make use of that one hour. We have some people who were coming down to sit in on our review of the selected research projects, apparently from the staff that would like to hear that. So we'll hold to that time, start that at 3:30.

And we'll try and take advantage of this one hour that John's giving us to take a look at the letter writing. See what we can get out of the way. But I will plan to take the break at 3:15. So we'll be off the record from this point.

(Whereupon, the meeting in the above-mentioned matter went off the record at 2:05 p.m.)

Presentation to ACRS Full Committee

US-APWR Design Certification

Chapter 9: Auxiliary Systems

September 6, 2012

Mitsubishi Heavy Industries, Ltd.

MHI Presenters

Kevin Lynn – Lead Presenter
Mitsubishi Nuclear Energy Systems, Inc.

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Introduction

- US-APWR DCD was submitted in December 2007
- DCD Chapter 9 describes auxiliary systems
- Chapter 9 was presented to US-APWR ACRS subcommittee on March 22-23, 2012
- Basic design concept of US-APWR is the same as a conventional 4 loop PWR
- Specific and unique features of US-APWR relevant to Chapter 9 will be summarized

Contents of DCD Chapter 9

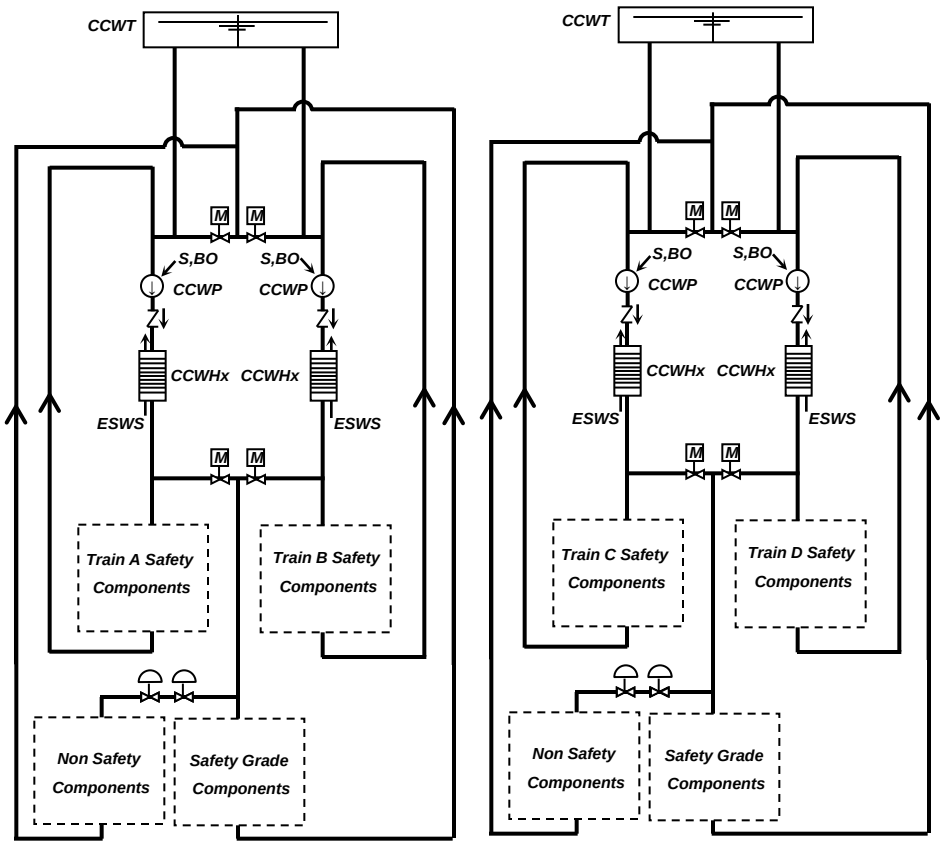
Section No.	Description
9.1	**Fuel Storage and Handling** Criticality safety of new and spent fuel storage; New and spent fuel storage; Spent fuel pit cooling and purification system; Light load handling system; and Overhead heavy load handling system
9.2	**Water Systems** Essential service water system; Component cooling water system; Potable and sanitary water systems; Ultimate heat sink; Condensate storage facilities; Chilled water system; Turbine component cooling water system; and Non-essential service water system
9.3	**Process Auxiliaries** Compressed air and gas systems; Process and post-accident sampling systems; Equipment and floor drain systems; Chemical and volume control system
9.4	**Air Conditioning, Heating, Cooling, and Ventilation Systems** Main control room heating, ventilation and air conditioning system; Spent fuel pool area ventilation system; Auxiliary building ventilation system; Turbine building area ventilation system; Engineered safety feature ventilation system; and Containment ventilation system
9.5	**Other Auxiliary Systems** Fire protection program; Communication systems; Lighting systems; GTG fuel oil storage and transfer system; GTG starting system; GTG lubrication system; and GTG combustion air intake, turbine exhaust, room air supply, and air exhaust systems

Contents of DCD Chapter 9

- Spent fuel pit (SFP) is described in DCD Section 9.1
- Several questions regarding SFP were asked during March ACRS meeting
- To address these questions:
  - ✓ MHI to provide response describing how SFP lines (safety) are separated from RWSP cleanup lines (non-safety) with remote manual valves
  - ✓ MHI to provide response with SFP boiling times given a loss of SFP cooling starting with water level at weir gate
  - ✓ SFP issues related to Fukushima will be addressed in new Technical Report to be submitted in February 2013

Contents of DCD Chapter 9

- Component Cooling Water System (CCWS) Design
  - ✓ 4 safety train configuration (each train consists of 1 CCWP and 1 CCW Hx)
  - ✓ Separated into 2 independent subsystems (each subsystem has 1 CCWT with an internal partition plate)
  - ✓ Non-safety supply headers can be automatically isolated

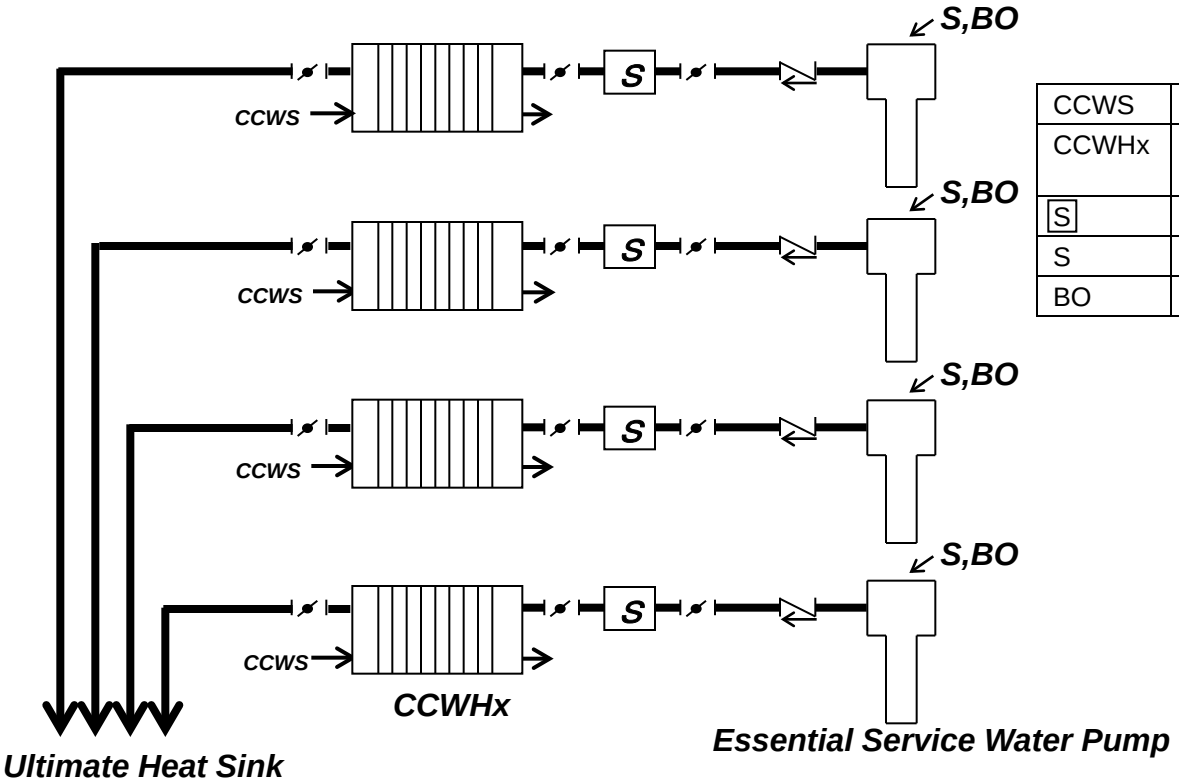


Legend

CCWT	Component Cooling Water Surge Tank
CCWP	Component Cooling Water Pump
CCWHx	Component Cooling Water Heat Exchanger
ESWS	Essential Service Water System
SFPHx	Spent Fuel Pit Heat Exchanger
P	Containment Spray Signal
S	Safety Injection Signal
BO	Blackout Signal
UV	Under Voltage Signal

Contents of DCD Chapter 9

- Essential Service Water System (ESWS) Design
  - ✓ Separated into 4 train configuration (each train consists of 1 ESWP)



Legend

CCWS	Component Cooling Water System
CCWHx	Component Cooling Water Heat Exchanger
[S]	Strainer
S	Safety Injection Signal
BO	Blackout Signal

Contents of DCD Chapter 9

- US-APWR uses GTGs instead of diesel generators
- GTGs are described in DCD Chapter 8
- DCD Section 9.5 describes the GTG support systems:
  - ✓ GTG fuel oil storage and transfer system
  - ✓ GTG starting system
  - ✓ GTG lubrication system
  - ✓ GTG combustion air intake, turbine exhaust, room air supply, and air exhaust systems
  - ✓ GTGs are air cooled and do not need cooling water system, so that subsection is omitted from Section 9.5

SER Open Item Resolution

- Chapter 9 SER (February 2012) identified 20 Open Items
- Current status is as follows:
  - ✓ 12 Open Items have been resolved
  - ✓ 8 Open Items are still in progress

LUMINANT GENERATION COMPANY

Comanche Peak Nuclear Power Plant, Units 3 and 4

597th ACRS Meeting

FSAR Chapters
5, 8, 10, 11, 12

September 6, 2012

Agenda

- Introduction
- Topics of Discussion with Subcommittee
  - Chapter 8
  - Chapter 10
  - Chapter 11
  - Chapter 12

Introduction

- R-COLA uses “Incorporated by Reference” methodology
- FSAR Chapters 5, 8, 10, 11, and 12 take no departures from US-APWR DCD
- No contentions pending before ASLB
- One outstanding issue in SER Chapter 8 (GDC 5)

Topics of Discussion with Subcommittee

- Chapter 8
  - Fire barriers in switchyard
  - GDC-5, controls, and equipment in switching station
  - Offsite power availability
- Chapter 10
  - FAC monitoring program
  - Lake Granbury statistics
  - Startup SG blowdown system isolation
- Chapter 11
  - Bypass around LW monitor tank RE and isolation valves
  - Interim Radwaste Storage Facility design
- Chapter 12
  - RP Supervisor to control receipt of byproduct, source, or SNM

Probabilistic Flood Hazard Assessment (PFHA)
Current and Planned RES Activities

Dr. Joseph Kanney
Hydrogeologist
RES/DRA/ETB

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
Full Committee Meeting

September 9, 2012

Motivation

- Discussions among staff in RES, NRO, NRR, and Regions
  - Identified several areas that may benefit from a more risk-informed approach with respect to external flooding events
    - Review of Safety Analysis Reports for COLA and ESP Applications
    - Risk Assessment Standardization Project
    - SPAR Model Development Program
    - Significance Determination Process
    - Accident Sequence Precursor Program
- Reviews by NRC Contractors, NRC/ACRS, GAO
  - "Synthesis of Extreme Storm Rainfall and Probable Maximum Precipitation in the Southeastern U.S. Pilot Region"", Draft NUREG/CR-7133 (NRC/USBR, 2012)
  - *"Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America", NUREG/CR-7046 (NRC/PNNL, 2011)*
  - *"NRC Natural Hazard Assessments Could Be More Risk-Informed"*, GAO-12-465 (GAO, 2012)
  - "*Review and Evaluation of the NRC Safety Research Program*", NUREG-1635, Volume 10 (ACRS, 2012)

Current Activities

- 2011 Long-term Research Plan Item *"Assessing Climate Variability Contribution to Risk at Nuclear Facilities"*
  - Originally scheduled for FY13 funding
  - Partially funded by NRR User Need (FY12-14)
    - Enhance treatment of external flood events in EE SPAR models
      - Probabilistic rainfall modeling
      - Flood frequency analysis
      - Continuous simulation approaches for flood frequency
    - "Data and Methodology for Probabilistic Rainfall Modeling" (Oak Ridge National Laboratory and Northeastern University)
      - Assess databases and probabilistic rainfall models

Proposed Near-Term Activities (FY13-14)

- Multi-Agency PFHA Workshop (January 29-31, 2013)
  - Joint NRO/NRR User Need Letter
  - Hosted by RES
    - Organizing Committee Co-Chairs:
      - Thomas Nicholson (RES/DRA)
      - Richard Raione (NRO/DSEA on rotation to RES/DRA)
  - Potential Co-Sponsors: NOAA, USGS, USBR, USACE, DOE
  - Proposed Topics:
    - Probabilistic modeling of local intense precipitation, riverine flooding, dam failure, storm surge, tsunami
    - Treatment of combined events
    - Interface with PRA models

Proposed Near-Term Activities (Cont.)

- Value of Paleoflood Information for Assessing Flooding Hazards at Nuclear Power Plants (USGS)
  - Assess potential for paleoflood information to improve flood risk assessment at nuclear power plant sites
- Regional Precipitation Frequency Analysis (USBR)
  - Investigate regional precipitation frequency approaches to extreme precipitation estimates (e.g., up to PMP)
- PFHA Technical Basis for Riverine Flooding (PNNL)
  - Riverine PFHA including extreme events and combined events (antecedent conditions)

Longer-Term Activities

- Coordinate with User Offices to evaluate options for addressing gaps identified by PFHA Workshop
  - User Offices draft additional User Need Letters
  - RES Develops Research Plan
- Evaluate options for PFHA Guidance
  - Develop NRC guidance
  - Adopting industry consensus standards
    - ANS-2.31 (currently under revision)
    - ANS-2.8 (currently under revision)

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Interim Staff Guidance 8, Revision 3 – *Burnup Credit in the Criticality Safety Analyses of PWR Spent Fuel in Transportation and Storage Casks*

Presentation to the Advisory Committee on Reactor Safeguards

September 6, 2012

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Agenda

Item	Topic	Presenter(s)	Time
1	Opening Remarks and Objectives	Dr. Michael Ryan, ACRS	10:15 – 10:20 a.m.
2	Staff Opening Remarks	Meraj Rahimi, NMSS	10:20 – 10:25 a.m.
3	Changes to ISG-8	Drew Barto, NMSS	10:25 – 10:55 a.m.
4	Cask Misloads	Nate Jordan, NMSS	10:55 – 11:15 a.m.
5	Public Comments and Proposed Resolution	Drew Barto, NMSS	11:15 – 11:30 a.m.
8	Industry Efforts on Burnup Credit	Dr. Albert Machiels, EPRI	11:30 – 11:50 a.m.
9	Industry Perspective on ISG-8	Marcus Nichol, NEI	11:50 – 12:00 p.m.
10	Committee Discussion	Dr. Ryan, ACRS	12:00 – 12:15 p.m.
11	Adjourn		12:15 p.m.

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Background

- Radiation and heat were the primary design drivers for older generation of transportation packages which were designed for short cooling times
- Sub-criticality became one of the primary design drivers for new generation of high-capacity casks for longer cooled fuel

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Background (cont.)

- To achieve high-capacity, cask designers eliminated flux traps (i.e. spacing between fuel) which are needed for the Fresh Fuel assumption, and relied on Burnup Credit instead
- Burnup Credit is credit for reduction in reactivity that occurs with fuel burnup due to the net reduction of fissile nuclides and the production of actinide and fission-product neutron absorbers

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Background (cont.)

- Based on available data in 2002, staff issued guidance on taking credit for the major actinide isotopes.
- In 2007, SRM SECY-07-0815 stated:

  "… staff should focus its effort on using burnup credit as a means to insert more realism into spent fuel transportation cask criticality analyses."

Background (cont.)

- In 2008, letter from ACNWM to Chairman Klein stated:
  - "… recommends that the staff take a risk-informed approach to evaluating Burnup Credit, including consideration of realistic and credible scenarios, probabilities, and consequences."
- In May 2012, staff issued draft ISG 8, Rev.3, for public comment. This ISG provides guidance for taking credit for actinides and fission products

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Major changes to ISG-8

- Credit for minor actinides and fission products
- Extend credit up to 60 GWd/MTU assembly-average
- Provide option for misload analysis with additional administrative loading procedures in lieu of burnup measurement

Expanding Technical Basis for Burnup Credit

- NUREG/CR-6979, *Evaluation of the French Haut Taux de Combustion (HTC) Critical Experiment Data* (2008)
- NUREG/CR-7012, *Uncertainties in Predicted Isotopic Compositions for High Burnup PWR Spent Nuclear Fuel* (2011)
- NUREG/CR-7108, *An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses – Isotopic Composition Predictions* (2012)
- NUREG/CR-7109, *An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses – Criticality (k_{eff}) Predictions* (2012)

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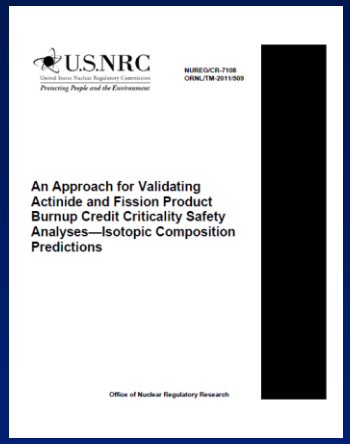
ISG-8 Revision 3 – Code Validation

- Availability of French HTC actinide data gives greater degree of confidence in actinide criticality validation than existed at the time ISG-8, Rev. 2 was published
- New chemical assay data expands the available database for fission product depletion validation and extends the range of applicability to higher burnups
- All available data used in NUREG/CR-7108 and -7109 to develop alternative isotopic depletion and criticality code validation methodologies.
- ISG-8, Revision 3 recommends crediting both actinides and fission products for up to 60 GWd/MTU

ORNL NUREG/CRs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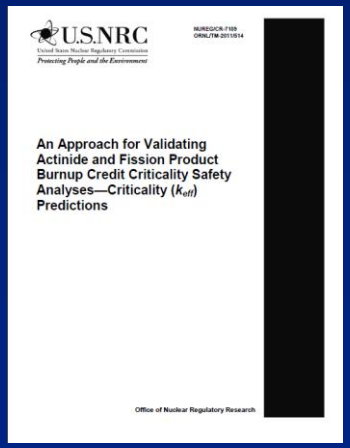
NUREG/CR-7108
ORNL/TM-2011/509

An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses—Isotopic Composition Predictions

Office of Nuclear Regulatory Research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NUREG/CR-7109
ORNL/TM-2011/514

An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses—Criticality (k_{eff}) Predictions

Office of Nuclear Regulatory Research

- Work performed under joint contract (SFST/NRR/NRO) through RES
- New isotopic depletion code validation methodologies and reference bias and bias uncertainty values
- New minor actinide and fission product criticality code validation methodology and reference bias value
- Provides recommendations regarding the use of the reference values, and the use of methodologies developed in the NUREG/CRs

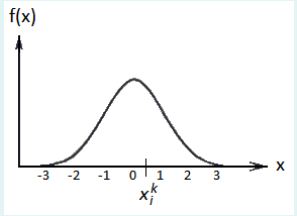
MC Uncertainty Sampling Method for Depletion Validation

$\overline{X}_n^b,\ \sigma_n^b$

Bias and bias uncertainty for nuclide *n*

c_n^b

Calculated concentration for nuclide *n*



Random number from the standard normal distribution

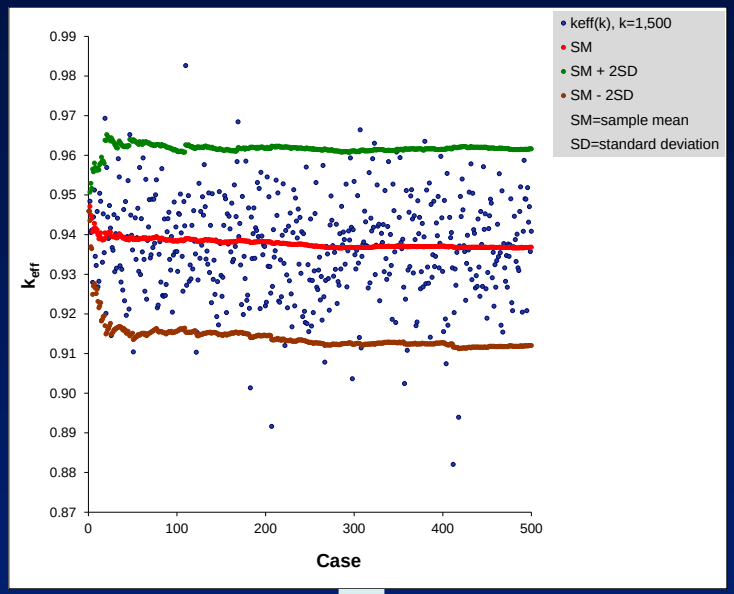
Concentration adjustment for nuclide *n*, burnup *b*, and criticality calculation *k*

$$c_{n,b}^k = c_{n,b} \cdot (\overline{X}_n^b + \sigma_n^b \cdot R_n^k\big|_{\text{normal}})$$

$n = n + 1$

Sampled nuclide concentrations for criticality calculation *k*

$k = k + 1$



k_{eff} mean and standard deviation

B&BU in k_{eff} based on the upper limit of the one-sided tolerance interval for 95% of the population and 95% confidence

PWR RCA Data for Depletion Validation

Isotope	No. of samples	Enrichment range (wt% ^{235}U)	Burnup range (GWd/MTU)	Isotope	No. of samples	Enrichment range (wt% ^{235}U)	Burnup range (GWd/MTU)
^{234}U	63	2.453–4.657	7.2–59.7	^{101}Ru	15	3.5–4.1	31.1–59.7
^{235}U	100	2.453–4.657	7.2–59.7	^{103}Rh	16	2.453–4.1	31.1–59.7
^{236}U	85	2.453–4.657	12.9–59.7	^{109}Ag	14	3.5–4.1	44.8–59.7
^{238}U	100	2.453–4.657	7.2–59.7	^{133}Cs	7	3.038 – 4.1	27.4–59.7
^{237}Np	44	2.453–4.657	16.0–59.7	^{143}Nd	44	2.453–4.657	16.0–59.7
^{238}Pu	85	2.453–4.657	12.9–59.7	^{145}Nd	44	2.453–4.657	16.0–59.7
^{239}Pu	100	2.453–4.657	7.2–59.7	^{147}Sm	32	2.453–4.657	23.7–59.7
^{240}Pu	100	2.453–4.657	7.2–59.7	^{149}Sm	28	3.5–4.657	23.7–59.7
^{241}Pu	100	2.453–4.657	7.2–59.7	^{150}Sm	32	2.453–4.657	23.7–59.7
^{242}Pu	99	2.453–4.657	7.2–59.7	^{151}Sm	32	2.453–4.657	23.7–59.7
^{241}Am	47	2.453–4.657	17.1–59.7	^{152}Sm	32	2.453–4.657	23.7–59.7
^{243}Am	48	2.63–4.657	17.1–59.7	^{151}Eu	21	3.5–4.657	23.7–59.7
^{95}Mo	15	3.5–4.1	31.1–59.7	^{153}Eu	27	2.453–4.657	23.7–59.7
^{99}Tc	25	2.453–4.1	16.0–59.7	^{155}Gd	27	2.453–4.657	23.7–59.7

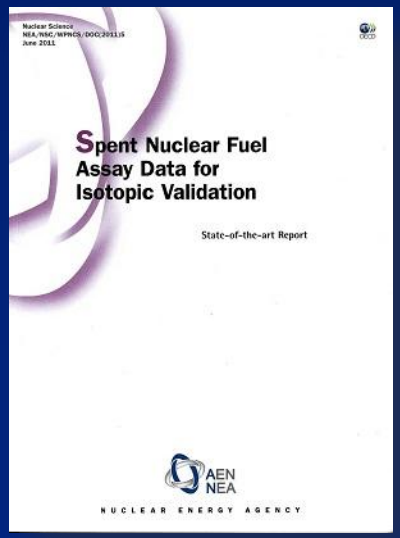
Radiochemical Isotope Assay for Depletion Validation

- Best practices in fuel radiochemistry have been developed over the past 30 years to ensure accurate measurements and representative samples

Fuel pellet sample at ORNL Hot Cell facility

- Sampling and fuel dissolution techniques
  - Dissolve fuel with cladding for complete isotope recovery from clad
  - Verify recovery from clad using spectral analysis of cladding
  - Separately analyze insoluble metallic residues (Mo, Tc, Ru, Rh, Pd, Ag, Sb) to ensure complete isotope collection
  - Obtain representative fuel segments for analysis that include both pellets and gaps to minimize biased sampling due to inhomogeneous fuel and migration of semi volatile species (e.g., ^{137}Cs)
  - Perform cross check analysis (^{148}Nd vs.^{137}Cs burnup to confirm no significant migration of Cs)
- Best practices in analytical methods for spent fuel assay documented in OECD report:

NEA/NSC/WPNCS/DOC(2011)5



http://www.oecd-nea.org/science/wpncs/ADSNF/SOAR_final.pdf

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Depletion Validation Results

Isotopic k_{eff} bias uncertainty (Δk_i) for the representative PWR SNF system model using ENDF/B-VII data ($\beta_i = 0$) as a function of assembly average burnup

Burnup Range (GWd/MTU)	Actinides Only Δk_i	Actinides and Fission Products Δk_i
0-5	0.0145	0.0150
5-10	0.0143	0.0148
10-18	0.0150	0.0157
18-25	0.0150	0.0154
25-30	0.0154	0.0161
30-40	0.0170	0.0163
40-45	0.0192	0.0205
45-50	0.0192	0.0219
50-60	0.0260	0.0300

Estimating Criticality (k_{eff}) Bias

- Uncertainty in the system k_{eff} is propagated from the cross section uncertainty using the sensitivity coefficient:

$$\sigma_{k_{eff}}\left(\frac{\%\Delta k}{k}\right)=\sigma_{\sigma}\left(\frac{\Delta\sigma}{\sigma}\right)\times S\left(\frac{\Delta k/k}{\Delta\sigma/\sigma}\right)*100\%$$

- Fundamental basis for this approach is that biases caused by nuclear data errors are bounded by the nuclear data uncertainties
- Uncertainty therefore gives an upper bound for the magnitude of the bias

Criticality Validation Results

- Uncertainty in k_{eff} due to nuclear data uncertainties investigated for SNF configurations as a function of burnup and a variety of other relevant parameters

- Uncertainty determined to be < 1.5% of the reactivity worth of the minor actinides and FPs in all cases considered

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ORNL NUREG/CR Recommendations

- Applicant may use the reference bias and bias uncertainty numbers developed by ORNL in lieu of an explicit depletion or minor actinide and fission product criticality validation, provided:
  - the same code and cross section data are used in the applicant's analysis
  - the applicant's storage or transportation system is demonstrated to be similar to that evaluated in the NUREG/CRs
- Applicant should perform traditional criticality code validation for major actinides using MOX and HTC data

Code Validation – ISG-8, Revision 3 Recommendations

	Major Actinides	Minor Actinides and Fission Products
Criticality Analysis	Applicant should perform analysis with Fresh UO_2, MOX, & HTC experiments	Use ORNL-supplied bias number
Isotopic Depletion Analysis	Use ORNL-supplied bias and bias uncertainty numbers, or use ORNL-developed validation methodologies	

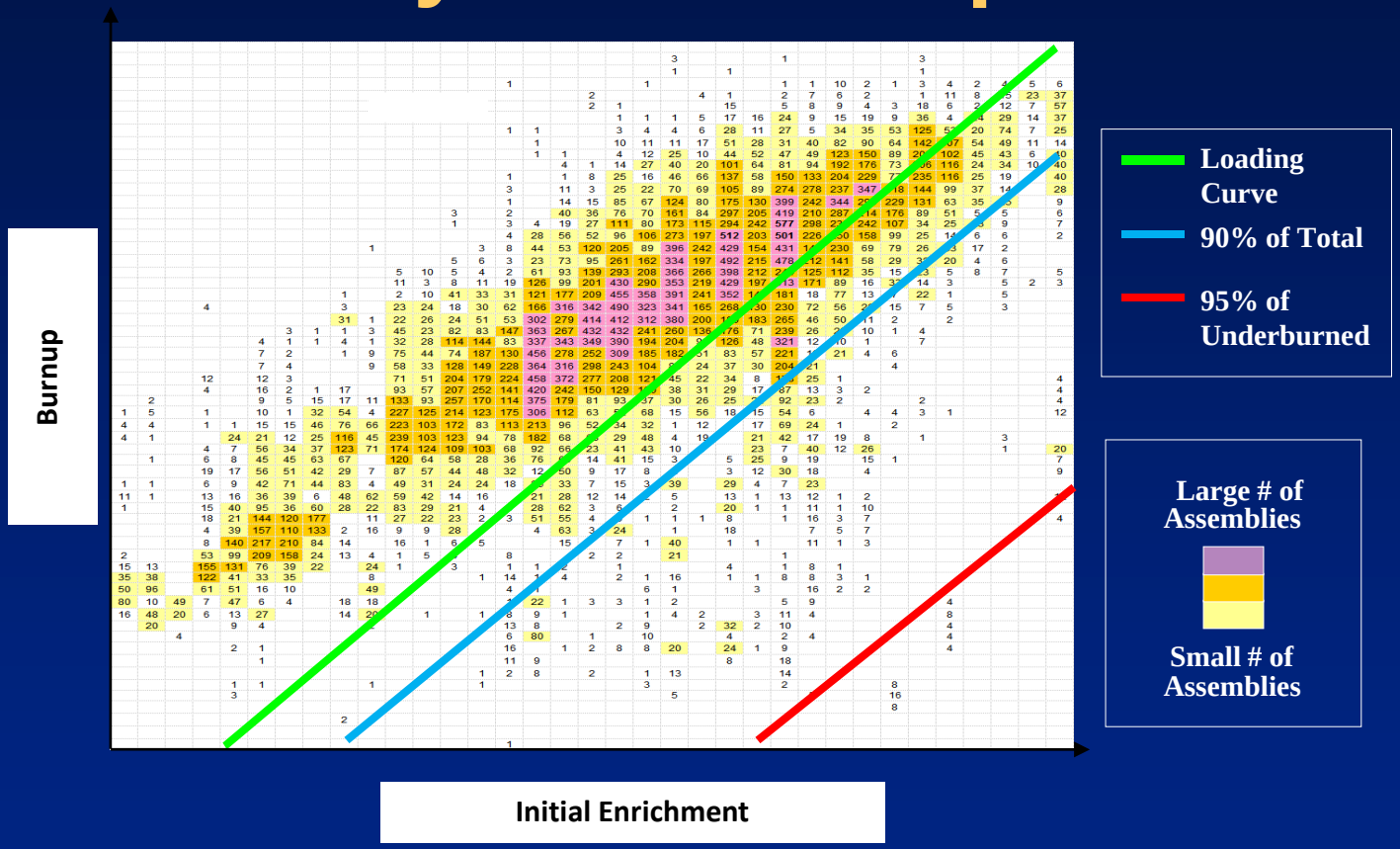
ISG-8 Revision 3 – Burnup Measurements

- NUREG/CR-6955, “Criticality Analysis of Assembly Misload in a PWR Burnup Credit Cask” (2008)
- NUREG/CR-6988, “Review of Information for Spent Nuclear Fuel Burnup Confirmation” (2009)
- RES report: *Estimating the Probability of Misload in a Spent Fuel Cask* (2011)
- ISG-8 modified to allow misload analysis combined with additional administrative procedures in lieu of direct measurement

Misload Analyses

- Single *severely* underburned misload, chosen such that reactivity bounds 95% of the underburned fuel population with 95% confidence
- Multiple *moderately* underburned misloads, chosen such that half the cask is filled with a fuel assembly that bounds the reactivity of 90% of the total discharged fuel population
- Reduced administrative margin ($\Delta k_m \geq 0.02$)
- Additional administrative procedures, such as identification of high reactivity fuel prior to and after loading, or independent reviews of cask loading process

Misload Analysis Fuel Population



From the 2002 EIA RW-859 Fuel Database

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Misload Report

- Purpose: determine if misloads are credible events
- Reviewed cask misload events to determine underlying causes and to identify common failure modes
- Calculated the probability of single or multiple cask misloads using two separate methods
  - Empirically from actual misload data
  - Using an event tree model
- Considered impact of burnup on misload probability

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Cask Misload Events

- **Palisades**: Calculation for cooling time was based on planned loading date, was not updated when loading date changed. 5 casks, 11 assemblies misloaded.
- **North Anna & Surry**: Cask design allowed for asymmetrical decay heat limits. Written procedures did not adequately explain this requirement leading to repeated errors. 11 casks, ~19 assemblies misloaded.
- **Grand Gulf**: Improper use of database containing incomplete information led to loading of assemblies exceeding allowed decay heat. 4 casks, 34 assemblies misloaded
- **McGuire (near misload)**: Crane picked up incorrect assembly adjacent to the correct assembly. Error caught while assembly was being lowered

Total of 20 casks misloaded out of 1200 → ~10^{-2} per cask

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Misload Events – Corrective Actions

- **Palisades**: Added a procedure for fuel selection and improved the fuel database to include fuel cycle date information.
- **North Anna & Surry**: Fixed procedure to include explanation of asymmetrical decay heat limits.
- **Grand Gulf**: Added a procedure for developing the necessary databases and calculations for selecting fuel.

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Misload Conclusions

- Misload events are credible
  - Empirical probability: 20 misloads / 1200 casks loaded ≈ 10^{-2} per cask
  - Event Tree Model probability ≈ 10^{-3} per cask
- Based on event tree model and empirical data, misloads are most likely caused by errors in the planning process
- Event is likely to involve multiple assemblies and casks

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Information Notice on Misloads

- Coordinating with NRR, NRO, and RES
- IN to discuss both spent fuel pool and dry storage cask misloads
- Misloads are credible and most result from systematic failures that can involve multiple assemblies
- Complicated loading patterns can increase likelihood
- Efforts to reduce misloads should focus on procedures for move planning and the accuracy of inventory data

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Public Comments on Draft ISG-8

- Received comments from:
  - Nuclear Energy Institute
  - Holtec International
  - Nuclear Consultants.com
- Major comments and proposed resolutions

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Provide flexibility for alternative validation methodologies

- Validation methodology recommended by ISG-8 represents one method that has been reviewed in detail by the staff and found to be acceptable
- ISG does not exclude alternative methodologies
- Revised ISG text to state that alternative methodologies should be considered on a case-by-case basis

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Remove burnup measurement

- Measurement recommendation maintained in ISG as an alternative to misload analysis/admin procedures
  - Allows flexibility to applicants if the misload analysis criteria is too restrictive for their specific design
  - Future measurement techniques may make measurement option more appealing

Modify administrative loading procedures

- Industry proposed procedures should already be incorporated into cask and site loading procedures; not specific to burnup credit; e.g.:
  - Verify the identity of the fuel assembly prior to loading it into the cask
  - Verify the identity of the fuel assemblies loaded into the cask prior to closing the cask
  - Verify the burn-up values of each fuel assembly to be loaded into the cask from a source QA record prior to loading the first assembly

Modify administrative loading procedures (cont'd)

- ISG procedures are intended to be *additional* procedures for burnup credit cask loading, targeted at reducing likelihood or consequences of high-reactivity misload, e.g.:
  - Soluble boron to offset reactivity increase of potential misload during loading and unloading
  - Verification of the location of high reactivity fuel (i.e., severely underburned or fresh fuel) in the spent fuel pool both prior to and after loading
  - Independent, third-party verification of the fuel selection process
- *Recommended* procedures; list not intended to be all-inclusive

Revise misload analysis recommendations

- Justification of 0.02 Δk_m for misload analyses
- Single fresh fuel assembly is acceptable, however:
  - procedures should prevent fresh fuel misloads
  - ISG recommends “reasonably bounding” single misload (95/95 level)
- Multiple assemblies 25% underburned is more simple, however:
  - Depends on loading curve (could be less restrictive than proposed in ISG)
  - ISG recommendation (bounds 90% of total inventory) allows this analysis to be omitted if the loading curve already encompasses 90% of fuel

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Other Comments

- Credit for additional isotopes:
  - Modified to state that additional isotopes may be credited, provided the bias and bias uncertainty is quantified
- BWR burnup credit:
  - Upcoming RES user need for BWR burnup credit
  - Revised ISG to state that BWR burnup credit analyses to be reviewed on case-by-case basis
- Applicability to non-intact fuel
  - Revised this section to include undamaged and damaged fuel (per ISG-1), provided fuel reconfiguration and any additional uncertainties are considered

Other Comments (cont'd)

- Separate bias and bias uncertainty terms:
  - β_i = bias in k_{eff} due to depletion code; added to calculated k_{eff}
  - Δk_i = uncertainty in β_i; statistically combined with other calculation uncertainties
  - Δk_x = uncertainty in k_{eff} due to uncertainty in minor actinide and fission product cross-section data; treated as bias added to calculated k_{eff}
- k_{eff} bias for other criticality codes:
  - Δk_x = 1.5% of minor actinide and fission product worth for SCALE code system with ENDF/B-V, -VI, or –VII data
  - Maintain 3.0% recommendation for other criticality codes (MCNP)
  - Additional research underway to justify lower value for other codes

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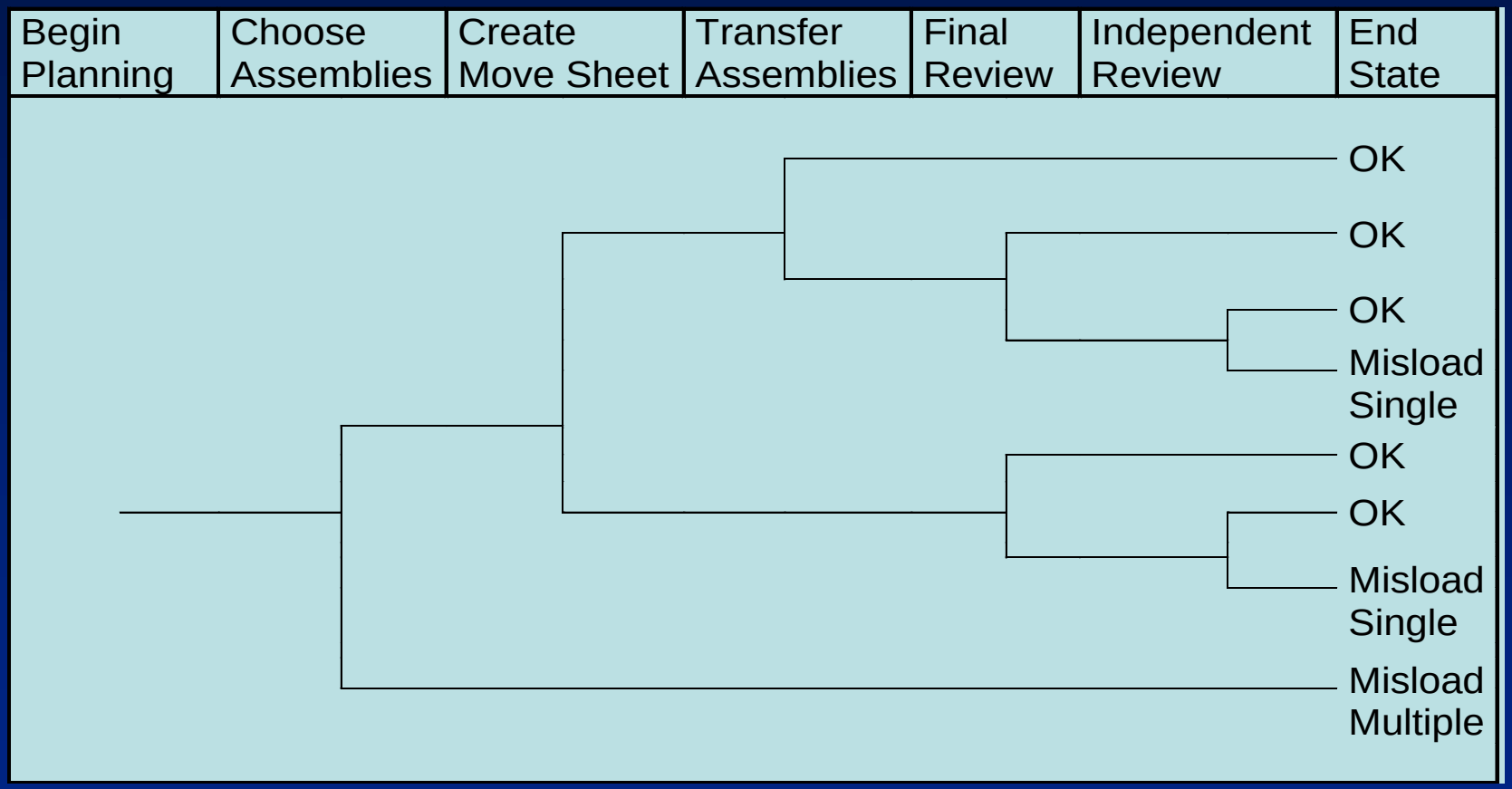
Conclusions and Next Steps

- ISG-8, Revision 3 extends the technical basis for burnup credit to fission products and minor actinides
- Provides alternative to confirmatory burnup measurement
- Generally well-received by industry, with some comments
- Plan to publish final ISG by the end of September
- BWR burnup credit research initiated

Backup Slides

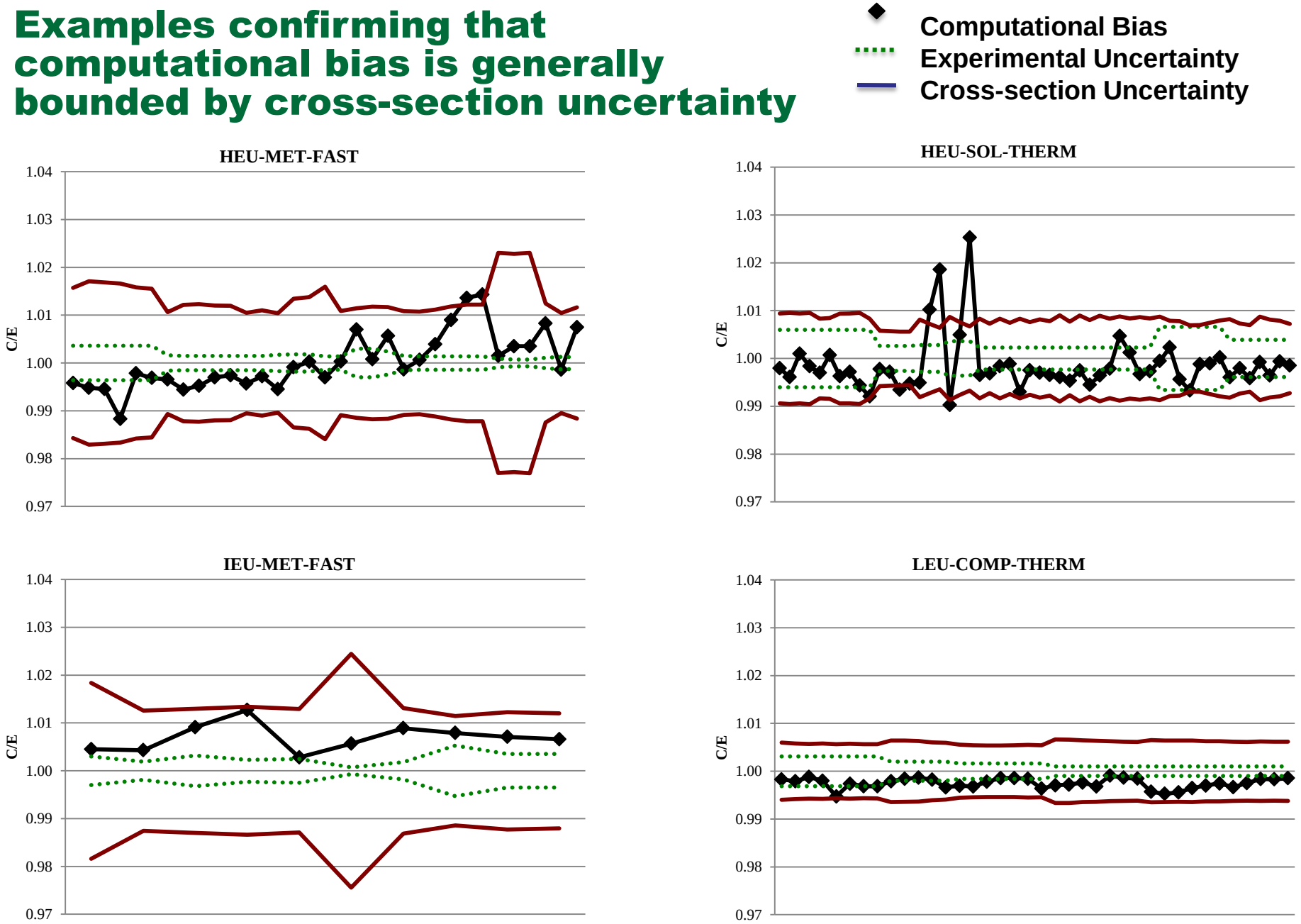
Event Tree


Begin Planning
Choose Assemblies
Create Move Sheet
Transfer Assemblies
Final Review
Independent Review
End State
OK
OK
OK
Misload Single
OK
OK
Misload Single
Misload Multiple

RCA Data (100 PWR fuel samples)

Reactor	Measurement Laboratory	Experimental Program	Assembly Design	No. of Samples/ Fuel Rods	Enrichment (wt % ^{235}U)	Burnup (GWd/MTU)
Trino Vercellese	Ispra, Karlsruhe	JRC	15 × 15	15/5	2.72, 3.13, 3.897	7.2–17.5
	Ispra, Karlsruhe	JRC	15 × 15	16/5	3.13	12.9–25.3
Obrigheim	Ispra, Karlsruhe	JRC	14 × 14	10/6	3.00	17.1–37.5
	ITU, IRCh, WAK, IAEA	ICE	14 × 14	5/5	3.13	27.0–29.4
H. B. Robinson-2	PNNL	ATM-101	15 × 15	4/1	2.561	16.0–31.7
Turkey Point-3	Battelle-Columbus	NWTS	15 × 15	5/1	2.556	30.5–31.6
Calvert Cliffs-1	PNNL, KRI	ATM-104	14 × 14	3/1	3.038	27.4–44.3
	PNNL	ATM-103	14 × 14	3/1	2.72	18.7–33.2
	PNNL, KRI	ATM-106	14 × 14	3/1	2.453	31.4–46.5
Takahama-3	JAERI	JAERI	17 × 17	13/3	2.63, 4.11	17.4–46.2
TMI-1	ANL	DOE YMP	15 × 15	11/1	4.013	44.8–55.7
	GE-VNC	DOE YMP	15 × 15	8/3	4.657	22.8–29.9
Gösgen	SCK•CEN, ITU	ARIANE	15 × 15	3/2	3.5, 4.1	29.1–59.7
GKN II	SCK•CEN	REBUS	18 × 18	1/1	3.8	54.1

Examples confirming that computational bias is generally bounded by cross-section uncertainty



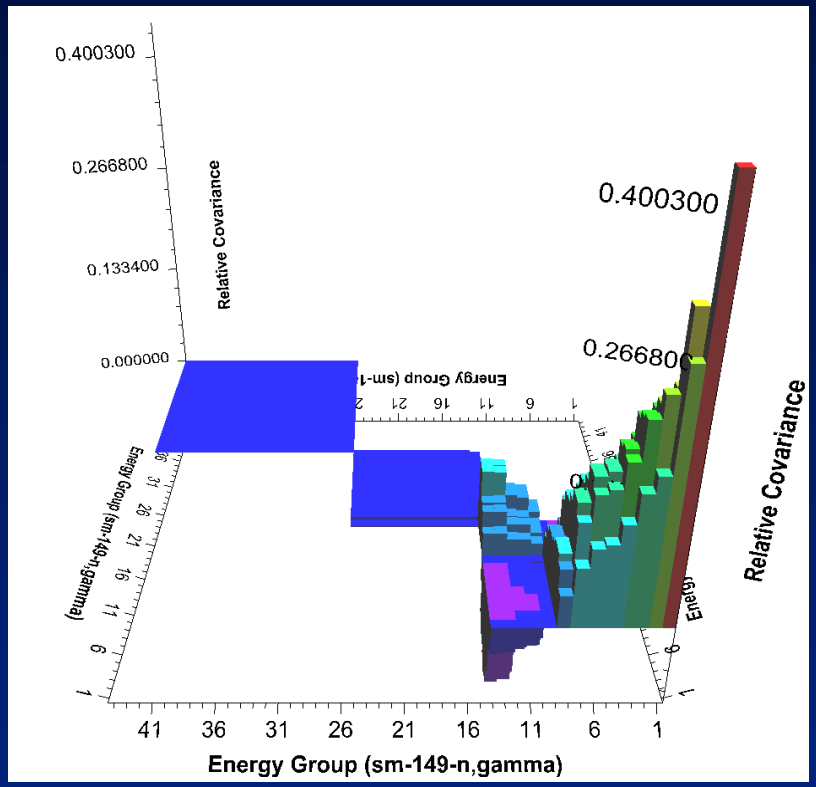
Example Results

Spent fuel pool and GBC-32 cask, fuel burned to 40 GWd/MTU

Uncertainty in k_{eff} due to uncertainty in nuclear data

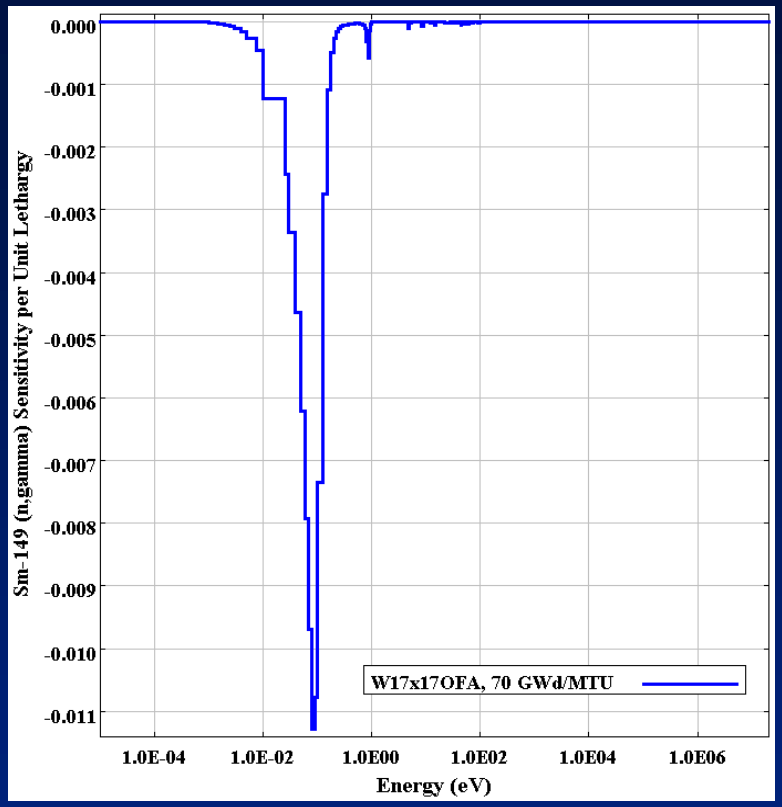
	Uncertainty (%Δk/k)	
Uncertainty Source	GBC-32	SFP
All nuclides	0.512	0.491
Actinides-only	0.496	0.480
Structural Materials	0.111	0.073
Primary 6 FP	0.049	0.047
Next 10 FP	0.024	0.023
All Other FP & Actinides	0.037	0.044

Uncertainty Analysis



Covariance Data $[(\Delta\sigma/\sigma)^2]$

&



Sensitivity Data $\{(\Delta k/k) / (\Delta\sigma/\sigma)\}$

combined using appropriate matrix algebra to yield uncertainty in k_{eff} due to nuclear data uncertainties

Burn-up Credit for Spent Nuclear Fuel Storage Casks and Transport Packages

Industry Perspective

Marc Nichol

Nuclear Energy Institute

ACRS Meeting

September 6, 2012

NEI

NUCLEAR ENERGY INSTITUTE

Industry feedback on ISG-8 Revision 3

- Generally a large improvement from revision 2
  - Greater utilization of burn-up credit
  - Some use of risk insights
  - Improved flexibility
- Opportunity for further improvements
  - Burn-up verification
  - Depletion validation – alternative methods
  - Depletion validation – additional isotopes
  - Burn-up credit – applicability to BWR
  - Dual uses of guidance

NEI

Burn-up verification method should most effectively address the situations that could lead to a misload

- General categories of potential misload
  1. Loading the wrong fuel assembly
  2. Calculating a burn-up value higher than actual
  3. Assigning the wrong burn-up value to a fuel assembly

In-pool burn-up measurements would not be effective in preventing misloads

- Ability to prevent misload is limited
- Mitigate consequence of misload
  - Less effective than “by design”
- Inaccurate and problematic to implement
- Provide burn-up “value”
  - Less accurate/reliable than reactor records

Most effective burn-up verification method is a "combination" approach (defense-in-depth)

1. Preclude misload from occurring
   - Administrative controls
     - Follow well-accepted QA practices
     - Focus on preventing misload, not on mitigating consequences
     - Improve based upon OE
2. Ensure if a misload occurs, remains sub-critical
   - Misload analyses
     - Safety is inherent in the design
     - Use appropriate assumptions
     - Ensure it is administratively simple

NEI

Draft Regulatory Guide 1290, *"Design-Basis Floods for Nuclear Power Plants"*

Dr. Joseph Kanney
Hydrogeologist
RES/DRA/ETB

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
Full Committee Meeting

September 6, 2012

Outline

- Background
- Topics Common to Most Flooding Mechanisms
  - Site Hydrologic Description
  - Design Storm Reports
  - Nonstationarity
  - Deterministic vs. Probabilistic Analyses
- Individual Flooding Mechanisms
  - Local Intense Precipitation
  - Riverine Flooding
  - Dam Failure
  - Surge, Seiche and Tsunami
  - Ice Effects
- Combined Events
- Status of Concurrence Reviews

Why Update This Guide?

- New data
  - New storms, precipitation and flood records
  - High-resolution topographical data
    - Digital Elevation Maps (DEMs), LIDAR
- Advances in analytical methods and tools
  - 2D and distributed hydrological models
  - Coupled wind-wave surge models
  - Online databases, Geographical Information Systems (GIS)
- Advances in computational resources
  - Dramatic increases in computer memory and data storage capacities
  - Dramatic increases in computational processing speed and affordability (e.g., PC Clusters)

Topics Common to Most Flooding Mechanisms

Site Hydrologic Description

- Safety-related elevations, structures, exterior accesses, equipment and systems should be described from a hydrologic perspective
- Existing topography of the site as well as any proposed changes
- Location, size, and other hydrologic characteristics of water bodies that may influence flooding at the site
  - streams, lakes, estuaries, shore regions, man-made channels, etc.
- Existing or proposed water control structures
  - Dams, levees, diversions, channels, intake/discharge structures, etc.
  - Structures upstream and downstream of the plant site
- Flooding history of the site and region
  - Major historical flooding events should be described in detail
    - Water levels, discharges, duration, etc.
- Information from paleoflood studies (where available)

Dated Design Storm Reports

- Probable Maximum Precipitation (PMP)
  - NOAA/NWS Hydrometeorological Reports
  - Example: HMR-51 (1978)
    - Covers most of Eastern U.S.
    - Most recent storm analyzed: 1974
- Probable Maximum Hurricane Wind Fields
  - NOAA Technical Report NWS-23 (1979)
  - Many well-documented storms since NWS-23 PMH parameter ranges adopted
  - PMH concept replaced by more physically-based maximum potential intensity (MPI)
- Bottom line: valuable information, but dated
  - Due diligence required

Non-Stationarity

- Sea-Level Rise (Coastal Sites)
  - Historical trends
    - NOAA/NOS data
- Potential Climate Change Impacts
  - Potential for accelerated SLR rates (Coastal Sites)
    - USGCRP recommended approach
  - Potential for increases in storm intensity (Coastal Sites)
    - Ambiguous (model-predicted changes vs. observations)
  - Potential for Increased Precipitation (Inland Sites)
    - Ambiguous at region and site-scale (models differ)
  - Potential for Increases in stream discharge (Inland Sites)
    - Ambiguous (model-predicted changes vs. observations)

Deterministic vs. Probabilistic Analyses

- NRC staff has mainly relied on deterministic approaches to design-basis flood estimation: hierarchical hazard assessment (HHA)
  - progressively refined, stepwise estimation of site-specific hazards
  - most conservative plausible assumptions consistent with available data
  - NUREG/CR-7046 provides guidance and illustrative case studies for applying HHA to a variety of flooding mechanisms
- Probabilistic characterization of extreme floods by various mechanisms, or combinations of mechanisms will be accepted on a case-by-case basis
  - NRC staff does not provide specific guidance on probabilistic flood hazard analysis techniques at this time
  - NRC staff currently uses combined flooding event scenarios from ANS-2.8-1992
    - average annual probability of exceedance of less than 1E-6
  - Reasonable criterion to apply to design-basis flood estimates arrived at via probabilistic methods assuming that reasonable confidence limits can be established

Individual Flooding Mechanisms

Local Intense Precipitation

- Precipitation event occurring at the immediate plant site
  - Adequacy of site drainage systems (including drainage from roofs of structures) and adjacent drainage areas
  - Always examined irrespective of the plant grade elevation with respect to nearby rivers, lakes, or other water bodies
- Key elements
  - The site drainage system description
  - Design storm
    - Area, duration, and temporal distribution of rainfall intensities
    - Guidance provided by the National Weather Service (e.g. HMR-52)
  - Models and associated parameters used to estimate the generation of surface runoff from the design storm
  - Models and associated parameters used to estimate conveyance of the surface runoff away from the site
- Analysis should address potential for the site drainage system effectiveness to be compromised
  - Potential for blockage during storm events by water born-debris

Riverine Flooding

- Flooding hazards at the power plant site caused by severe hydrometeorological conditions occurring over watersheds that communicate with the site
- RG-1.59, Rev. 2, Appendix B (maps, tables from envelope curve formulas) no longer recommended for screening
- Deterministic analysis aimed at determining the most extreme credible flood, also known as the probable maximum flood (PMF)
  - Defined as the hypothetical flood (peak discharge, volume, and hydrograph shape) considered the most severe reasonably possible
  - Application of hypothetical extreme rainfall event (e.g., PMP) along with other hydrologic factors favorable for maximum flood runoff (combinations of processes occurring in the drainage basin above the site and at site)
  - Appropriate combinations to consider should be determined on a site-specific basis.
    - Sequential precipitation events
    - Timing, centering, and duration of precipitation
    - Seasonal variation of precipitation and antecedent moisture
    - Snowpack accumulation, snowmelt, and meteorological factors influencing snowmelt timing
    - Flood-caused dam failures
    - Reservoir elevations
    - Superimposed wind waves

Riverine Flooding: Key Elements (I)

- Design Rainfall - Evaluate the precipitation flux over the watershed as a function of space and time
  - Developed from the hypothetical extreme rainfall event
    - Storm-centered, area-averaged PMP, in most cases
  - Optimal temporal distribution, optimal centering and orientation over the drainage basin
  - Movement of the storm along the basin axis
  - Procedures recommended by the National Weather Service
- Rainfall-Runoff Analysis – Evaluate effective precipitation flux as a function of space and time
  - Description of the watershed (area, topography, soil types, land cover)
  - Rainfall-runoff transformation function
    - unit or synthetic hydrograph

Riverine Flooding: Key Elements (II)

- Flood Routing - Route the precipitation excess to the plant site to determine flood hydrograph.
  - Description of the stream channel network
    - Reach lengths, cross sections, and cross-section locations
    - Channel roughness coefficients,
  - Flood routing method
    - 1D vs. 2D models
    - Dynamic vs. Steady
  - Initial and boundary conditions
- Validation exercises - Apply the analysis to historical floods, if available

Dam Failure

- Dams to consider for potential failures
  - Dams upstream of the plant site
  - Dams not upstream of the plant, but whose failure may impact the plant because of backwater effects
  - Water-storage or water-control structures located at or above the grade of safety-related equipment
    - Onsite cooling or auxiliary water reservoirs, onsite levees
- Screening may identify some dams that can be eliminated from more detailed consideration
  - Low differential head, small water volume stored, distance from plant site, major intervening natural or reservoir detention capacity

Dam Failure (Cont.)

- Dam failure categories (predominant mode of failure)
  - Hydrologic dam failure
  - Seismic dam failure
  - Dam failure from other causes (sunny-day failures)
- Consider potential for multiple dam failures and the domino failure of a series of dams
- Dynamic hydraulic models to route the flood wave resulting from dam failure to the plant
- Examine sensitivity of flood stage and water velocity estimates
  - Reservoir levels, reservoir inflow conditions
  - Tailwater conditions before and after dam failure
- Consider transport of sediment and debris by the flood waters

Coastal Flooding

- Coastal refers to the near-shore regions of any water body (e.g., ocean, lake, bay, estuary, etc.) where surge, seiche, or tsunami phenomena may occur, not just regions adjacent to the open ocean
- In coastal regions, flooding hazards result from storm surges, seiches, and tsunamis, along with coincident wave action caused by hydrometeorological activity
- Wind-generated wave activity that can occur independently of or coincidentally with storm surge or seiche should be included in surge and seiche flood hazard analyses
- Available records should be used to characterize the wave climate near the site using measures such as significant and maximum wave heights
- Wave setup, runup, splash, or overtopping, as appropriate, should be considered
- Potential impact of tides should also be included in surge and seiche flooding estimates

Storm Surge

- Examine all storm types appropriate for region
  - tropical cyclones (hurricanes)
  - extratropical cyclones
  - squall lines and hybrid storms
- Simplified conservative methods for screening of hurricane storm surge
  - RG-1.59, Rev. 2, Appendix C maps, tables for screening are obsolete
  - Draft NUREG/CR-7134 proposes updated screening approach
- Detailed analysis required when storm-surge flooding cannot be eliminated from consideration by simplified methods

Detailed Storm Surge Analysis

- Detailed analysis of historical storm events in the region, when available
- Augment historical record with synthetic storms (modeling)
  - Models should be validated using historical storm information and data in the region of interest
  - Models parameterized to account for
    - Conditions more severe than those in the historical record, but considered to be reasonably possible on the basis of climatological and meteorological reasoning
    - Uncertainties
- Current state of the art in storm-surge modeling
  - Coupled hydrodynamic ocean circulation and wave models
  - Both models driven by a planetary boundary layer model that provides the atmospheric forcing
  - High-resolution bathymetric and topographic data

Seiche

- The potential for seiche to impact the site should examined for coastal locations (including lakes, semi-enclosed bays, etc)
- Consider forcing of oscillatory modes from a variety of potential sources
  - Local or regional forcing phenomena
    - Barometric pressure fluctuations
    - Strong winds, rapid changes in wind direction
    - Surge associated with passage of local storms
  - Distant but large forcing mechanisms
    - Distant storms, tsunami, or earthquake-generated seismic waves
- Estimate modes, magnitudes of oscillations in relevant waterbody
  - Waterbodies with simple geometries
    - Modes of oscillation can be predicted from the shape of the basin using analytical formulas
  - Most natural water bodies have variable bathymetry and irregular shorelines and may be driven by a combination of forcings
    - Seiche periods and water surface profiles should be determined through numerical long-wave modeling

Tsunami

- Tsunami hazard zones
  - Coastal sites : hazards from oceanic tsunamis
  - Inland sites: tsunami-like waves in water bodies in the region
    - Hill-slope failure or seismic sources
- Effects of tsunami or tsunami-like waves
  - Runup, flooding, erosion, and debris loads
  - Rundown or return flow of water (and debris)
- Screening
  - Regional or site specific survey of tsunamigenic sources
    - Potential near-field and far-field sources and mechanisms that could generate tsunamis
    - Relevant paleo-tsunami evidence should be assessed
- Detailed assessment
  - Postulation of probable maximum tsunami (PMT) source mechanisms
    - Location, dimensions, orientation, and maximum displacement
  - Estimation of PMT source characteristics,
  - Initiation of the PMT wave,
  - Propagation of the PMT wave from the source toward the site
  - Estimation of tsunami effects at the site

Ice Effects

- Potential for ice-jam formation should be assessed based on regional hydroclimatic conditions
  - air temperature characteristics
    - NOAA's National Climatic Data Center (NCDC)
  - Regional ice accumulation and ice jam formation history
    - U.S. Army Corps of Engineer's Ice Jam Database
- When the potential for ice formation cannot be ruled out, or is not clearly bounded by other flooding mechanisms, flooding hazards due to ice effects should be examined quantitatively
  - Ice-jam formation on nearby streams
  - Ice accumulation on site facilities
- Because of the much higher flows that usually prevail during spring breakup, breakup jamming is usually identified as the ice-related event of main concern for flood-hazard assessment
  - Flooding due to backwater effects of ice-jam formation downstream of the plant
  - Flooding due to breach of an upstream ice jam
- Predicting precise location and severity of ice jams is generally infeasible
  - Analyze impact of hypothetical ice jams at critical locations

Combined Events

- Extremely large floods of interest for design basis seldom the result of a single event or process
- Consideration of reasonable sequences and combinations of processes and events, based on regional or site-specific information
- Maximum water-surface elevation and maximum hydrostatic force may result from different combinations.
- Many hydrometeorological flood-causing phenomena can occur sequentially or concurrently because they are not truly independent mechanisms
  - Floods from precipitation events may occur concurrently with snowmelt floods
  - In coastal regions, the precipitation event may be a result of a tropical or extratropical cyclone
    - Stream flooding could coincide with a storm surge and wind-induced waves
  - In general, the effects of coincident wind-generated wave activity on the water levels should always be considered
- Credible combinations and sequences of hydrometeorological and nonhydrometeorological events
  - Astronomical high tides may combine with hydrometeorological events (e.g., storm surge) or seismic events (e.g., tsunami).
- NRC staff currently uses ANS-2.8-1992 guidance (average annual probability of exceedance of less than 1E-6) as a metric to evaluate combined event scenarios
  - Guidance on formal probabilistic flood hazard assessment approaches providing consistent treatment of combined events is lacking
  - Reasonableness of qualitative and quantitative probability estimates for combined events assessed on a case-by-case basis, based on regional or site-specific information

Concurrence Reviews

Office	Division	Status
ACRS	---	In progress
NRO	Site Safety & Environmental Analysis	In progress
NRR	Operating Reactor Licensing	*Reviewed*
	Risk Assessment	*Reviewed*
	Engineering	*Reviewed*
NMSS	Fuel Cycle Safety & Safeguards	*Reviewed*
Region I	Reactor Safety	*Reviewed*
Region II	Reactor Safety	*Reviewed*
Region III	Reactor Safety	*Reviewed*
Region IV	Reactor Safety	*Reviewed*

Plan to issue Draft Guide for public comment in Q1FY13

Thank You!

Questions?

Back-up Slides

Regulatory Basis

- 10 CFR Part 50, *"Domestic Licensing of Production and Utilization Facilities"*, Appendix A, "*General Design Criteria for Nuclear Power Plants*," General Design Criterion (GDC) 2, "*Design Bases for Protection Against Natural Phenomena*"
- 10 CFR Part 52, "*Licenses, Certifications, and Approvals for Nuclear Power Plants*"
- 10 CFR 100.20, "*Factors To Be Considered When Evaluating Sites*"
- 10 CFR 100.23, "*Geologic and Seismic Siting Criteria*"

Related NRC Guidance

- RG-1.70, Rev.3 "*Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants (LWR Edition)*"
- RG-1.206, "*Combined License Applications for Nuclear Power Plants (LWR Edition)*"
- NUREG-0800, "*Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants (LWR Edition)*"
- RG-1.102, "*Flood Protection for Nuclear Power Plants*"
- RG-1.200, "*An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities*"
- RG-4.7, "*General Site Suitability Criteria for Nuclear Power Stations*"

Related IAEA Guidance

- NS-R-1, "*Safety of Nuclear Power Plants: Design*"
- NS-R-3, "*Site Evaluation for Nuclear Installations*"
- GS-G-4.1, "*Format and Content of the Safety Analysis Report for Nuclear Power Plants*"
- NS-G-1.5, "*External Events Excluding Earthquakes in the Design of Nuclear Power Plants*"
- NS-G-3.5, "*Flood Hazard for Nuclear Power Plants on Coastal and River Sites*"
- NS-G-3.6, "*Geotechnical Aspects of Site Evaluation and Foundations for Nuclear Power Plants*"
- SSG-18, "*Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations*"

Technical Basis Update Research

- **NUREG/CR-6906**, "Tsunami Hazard Assessment at Nuclear Power Plant Sites in the United States of America"
- **NUREG/CR-7046**, "Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America"
- **Draft NUREG/CR-7131**, "Review of Probable Maximum Precipitation Procedures and Databases Used to Develop Hydrometeorological Reports,"
- **Draft NUREG/CR-7132**, "Application of Radar-Rainfall Estimates to Probable Maximum Precipitation in the Carolinas"
- **Draft NUREG/CR-7133**, "Synthesis of Extreme Storm Rainfall and Probable Maximum Precipitation in the Southeastern U.S. Pilot Region"
- **Draft NUREG/CR-7134**, "The Estimation of Very-Low Probability Hurricane Storm Surges for Design and Licensing of Nuclear Power Plants in Coastal Areas"

ELECTRIC POWER RESEARCH INSTITUTE

EPRI Work Relevant to Burnup Credit

Albert Machiels
Senior Technical Executive

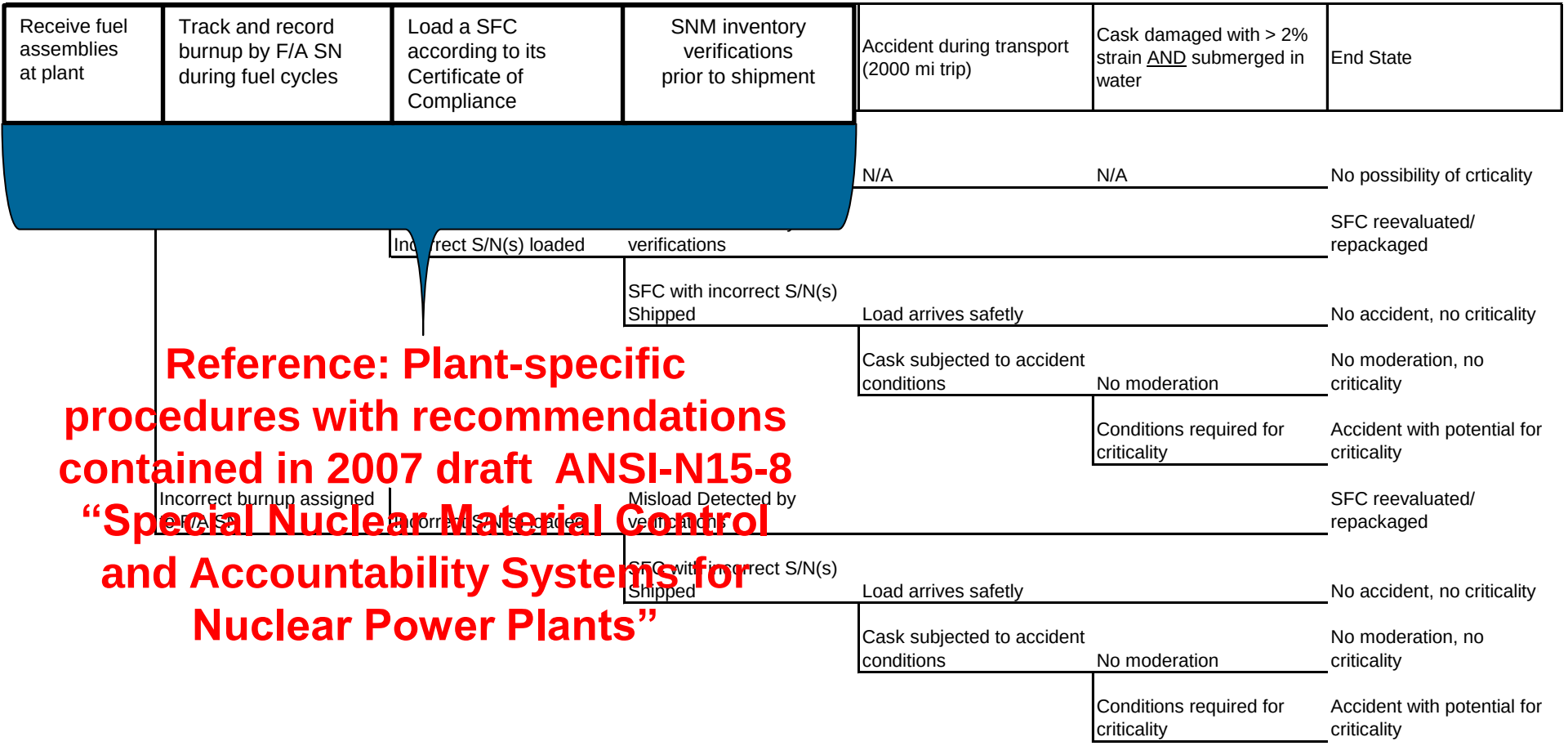
ACRS
September 6, 2012 Meeting

Contents

Introduction – Criticality Safety and Burnup Credit

- Criticality safety: key public safety concern
  - Standards & methodologies were originally developed for the front end of the fuel cycle with pure materials
  - Applying them to spent fuel is not as straightforward
    - ORIGEN follows >2000 nuclides
- "Fresh fuel assumption"
  - Significant conservatism
  - Low-capacity storage and transport systems (more systems, more operations, increased $)
    - May result in less overall safety (radiological ←→ non-radiological)
- Burnup credit (BUC): Getting credit for the reduced reactivity of spent fuel compared to fresh fuel
  - "Actinide-only", "Actinide + subset of fission products", "Full BUC"

Probability of Critical Event During Transportation EPRI Report 1016635 (December 2008)



Reference: Plant-specific procedures with recommendations contained in 2007 draft ANSI-N15-8 "Special Nuclear Material Control and Accountability Systems for Nuclear Power Plants"

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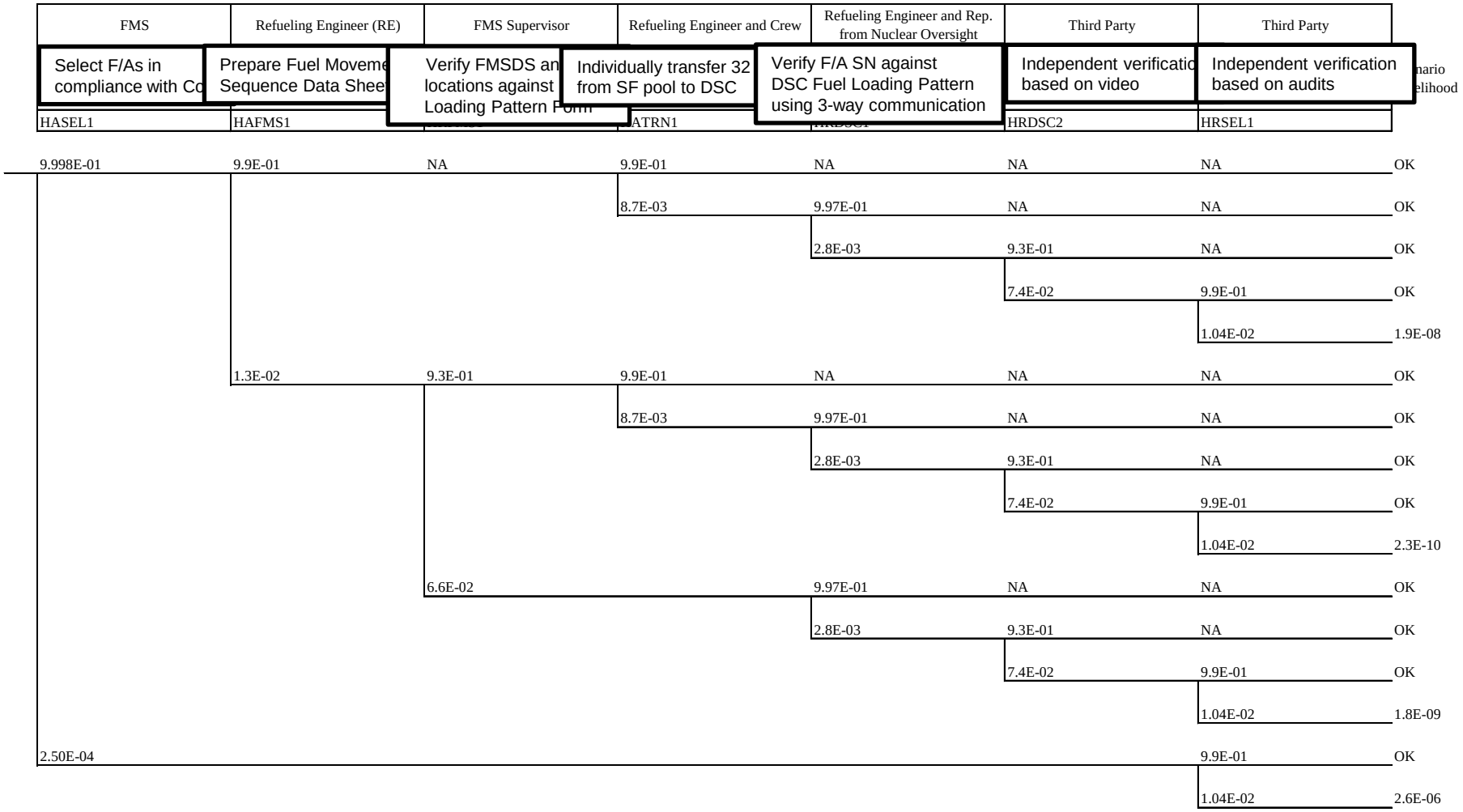
Quantification of Human Failure Events Leading to a Misloaded Dry Spent Fuel Cask

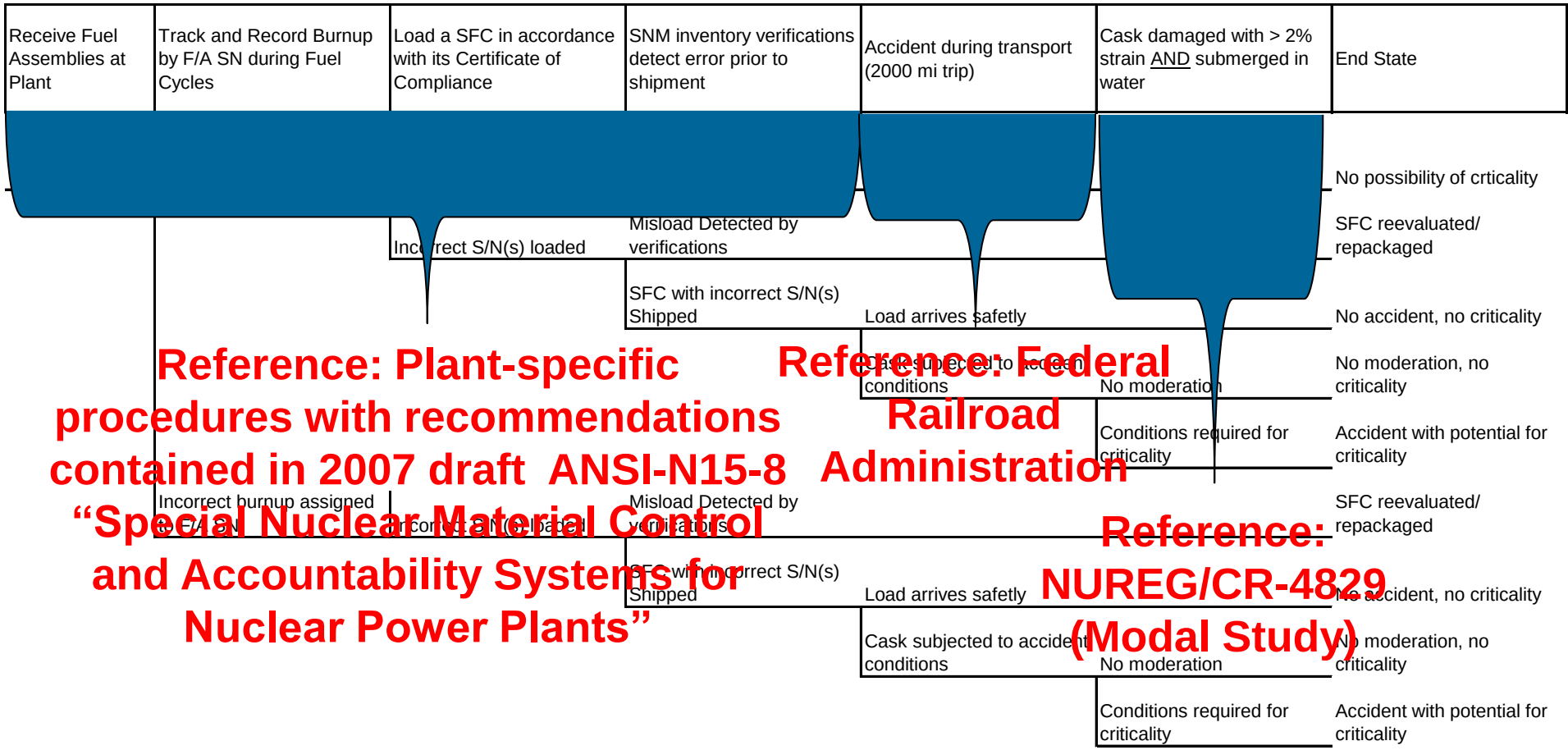


From EPRI Report 1016635

Total likelihood of a spent fuel cask shipment with one or more misloaded F/As = 2.6E-06

ELECTRIC POWER RESEARCH INSTITUTE

Probability of Critical Event During Transportation EPRI Report 1016635 (December 2008)



Reference: Plant-specific procedures with recommendations contained in 2007 draft ANSI-N15-8 "Special Nuclear Material Control and Accountability Systems for Nuclear Power Plants"

Reference: Federal Railroad Administration

Reference: NUREG/CR-4829 (Modal Study)

Likelihood of a potential criticality event during a 2000-mile railroad shipment of a cask designed for 32 PWR assemblies: ~1×10^{-16}/shipment

Burnup Credit Validation

- Main thrust: conservatively estimate loss of nuclear reactivity as a function of burnup (range: 0 to 60 GWD/MTU)
  - Including uncertainty of the estimate
- Alternate approach
  - Based on in-reactor measurements (flux maps)
    - Required as part of routine monitoring of power plant operations
  - Cooperative effort involving Duke-Energy, Studsvik Scandpower, and Dr. Dale Lancaster
    - Principal Investigator: Prof. Kord Smith (MIT)

Flux Maps: Individual Assembly Reaction Rates

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1							0.499 0.491 0.008			0.483 0.483 0.000					
2			0.369 0.389 -0.020			0.998 1.008 -0.006		0.996 0.991 0.004							
3								1.195 1.175 0.020		1.081 1.069 0.012		0.998 0.985 0.012		0.370 0.382 -0.012	
4		0.610 0.627 -0.017	0.997 0.994 0.003					1.315 1.323 -0.008							
5					1.309 1.298 0.010				1.330 1.331 -0.001		1.309 1.304 0.005		1.177 1.170 0.007		
6	0.484 0.479 0.004		1.082 1.071 0.011			1.331 1.332 -0.001									
7				1.191 1.179 0.011			1.276 1.287 -0.011			1.236 1.224 0.011			1.270 1.274 -0.004		
8	0.475 0.478 -0.003		1.196 1.183 0.013		1.232 1.224 0.008		1.209 1.206 0.003					1.317 1.319 -0.002	1.195 1.178 0.017	0.996 0.995 0.001	
9		0.958 0.951 0.007							1.278 1.272 0.006		1.332 1.317 0.014				0.497 0.501 -0.004
10												1.296 1.298 -0.002			
11	0.355 0.372 -0.018				1.306 1.323 -0.017			1.233 1.212 0.020			1.308 1.305 0.004				0.354 0.370 -0.015
12						1.294 1.305 -0.011			1.192 1.182 0.009			1.170 1.173 -0.003			
13			0.876 0.876 0.000		1.170 1.188 -0.018			1.196 1.183 0.013						0.369 0.383 -0.014	
14			0.369 0.395 -0.026				0.956 0.938 0.018			1.000 0.996 0.003		0.611 0.642 -0.032			
15					0.354 0.366 -0.012			0.475 0.476 -0.001						Reaction Rate SIMULATE-3 MEASURED S3-MEAS	

- Miniature fission chambers are inserted in the central instrument tubes of selected assemblies
- This is a high precision (<1% statistical error) measurement of the core-wide distribution of fission rates
- BOC calculations required by NRC to be within a prescribed tolerance of measurement - to assure core loading
- Required every 30 days by NRC to guarantee that the core is operating within design margins

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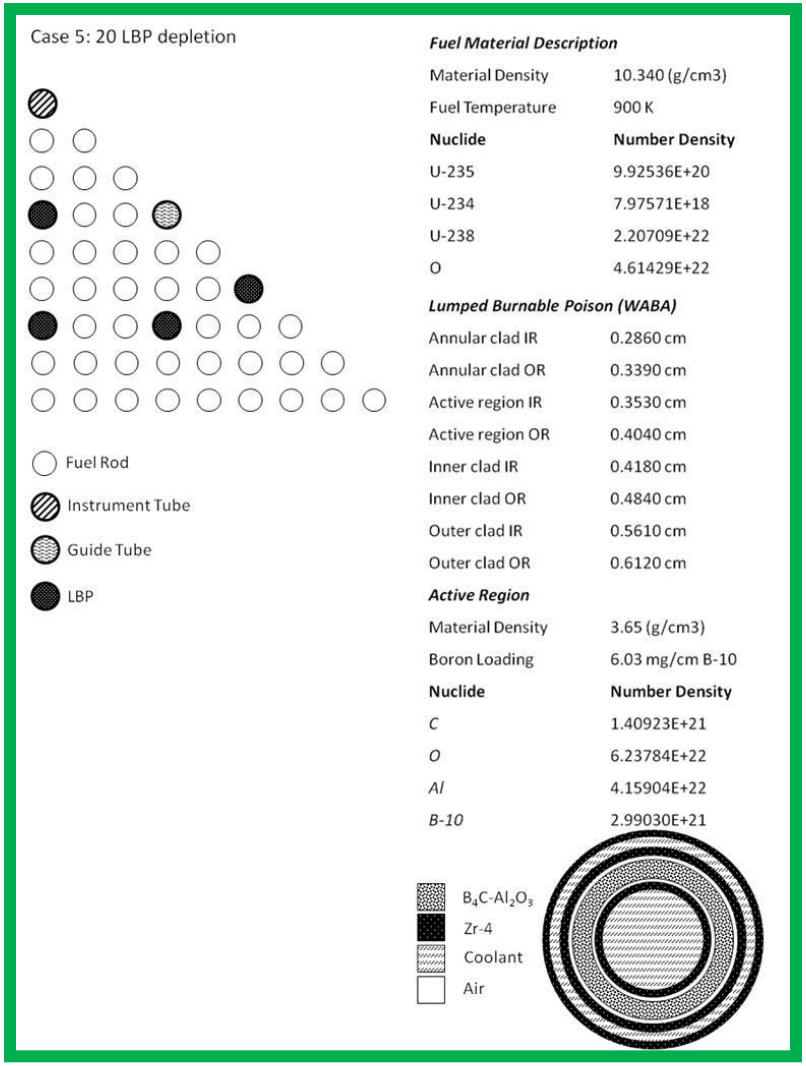
11 Reactivity Decrement Benchmarks for 17 x 17 PWR Fuel Designs

	Table 13.1 Benchmark Lattice Cases
1	3.25% Enrichment
2	5.00% Enrichment
3	4.25% Enrichment
4	off nominal pin diameter depletion
5	20 LBP depletion
6	104 IFBA depletion
7	104 IFBA plus 20 LBP depletion
8	high boron depletion=1500 ppm
9	branch to hot rack (150F coolant/fuel)=338.7K
10	branch to high rack boron = 1500 ppm
11	high power depletion*(power, coolant/fuel temp)

Measured Reactivity Decrement						
Burnup (GWd/T)						
Case	10	20	30	40	50	60
1	-0.1329	-0.2339	-0.3211	-0.3956	-0.4554	-0.5002
2	-0.1146	-0.2021	-0.2806	-0.3545	-0.4238	-0.4867
3	-0.1223	-0.2157	-0.2990	-0.3758	-0.4445	-0.5029
4	-0.1207	-0.2176	-0.3075	-0.3931	-0.4715	-0.5385
5	-0.2045	-0.2335	-0.2998	-0.3717	-0.4372	-0.4932
6	-0.1736	-0.2215	-0.2968	-0.3726	-0.4418	-0.5009
7	-0.2524	-0.2418	-0.2981	-0.3686	-0.4343	-0.4910
8	-0.1216	-0.2129	-0.2932	-0.3662	-0.4310	-0.4860
9	-0.1237	-0.2171	-0.2998	-0.3756	-0.4432	-0.5005
10	-0.0967	-0.1784	-0.2530	-0.3217	-0.3826	-0.4335
11	-0.1235	-0.2149	-0.2945	-0.3664	-0.4299	-0.4838



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Comparison between "Draft ISG-8, Rev 3" and "Depletion Benchmarks"

Bias + Uncertainty in Neutron Multiplication Factor		
Burnup	Draft ISG-8, Rev 3	Depletion Benchmarks
10	0.015	0.008
20	0.016	0.008
30	0.016	0.008
40	0.022	0.008
50	0.030	0.008
60	0.030	0.008

- Both results are for SCALE and ENDF/B-VII
- **"Depletion Benchmarks" uncertainty includes all nuclides** rather than the more limited number of nuclides allowed by Draft ISG-8, Rev 3
- "Depletion Benchmarks' value is dominated by measurement uncertainties. Draft ISG-8, Rev 3 values dominated by chemical assay uncertainties

Summary

- Alternative Approach: Reactor-based full burnup credit validation
  - Applicable to storage (wet and dry), transportation, disposal
  - Normal sequencing from reactor operation
- Spent High-burnup Fuel Transportation
  - Burnup credit is a high priority topic
    - Increased cask capacity (32 vs. 24 assemblies)
    - Loading a greater percentage of spent fuel population
  - Extremely low probability for the potential of a critical event during transportation of commercial spent high-burnup fuel

"Removal of extreme conservatism can result in an overall improvement in safety by balancing criticality risks with other operational risks" [C. Parks (ORNL), Closing Review Session of 2011 International Conference on Nuclear Criticality (ICNC2011)]

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  - *Transportation of Commercial Spent Nuclear Fuel – Regulatory Issues Resolution,* EPRI, Palo Alto, CA: 2010. 1016637. http://mydocs.epri.com/docs/public/000000000001016637.pdf
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- Misload Analyses
  - *Burnup Credit – Technical Basis for Spent-Fuel Burnup Verification,* EPRI, Palo Alto, CA: 2003. http://mydocs.epri.com/docs/public/000000000001003418.pdf
  - *Criticality Analysis of Assembly Misload in a PWR Burnup Credit Cask,* ORNL, Oak Ridge, TN: 2008. NUREG/CR-6955.

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- Depletion Benchmarks
  - *Benchmarks for Quantifying Fuel Reactivity Depletion Uncertainty,* EPRI, Palo Alto, CA: 2011. 1022909. http://mydocs.epri.com/docs/public/000000000001022909.pdf
  - Smith, K., D. Lancaster, and A. Machiels, *Experimental Benchmarks for Quantifying Fuel Reactivity Depletion Uncertainty,* ICNC2011, Edinburgh (Scotland), September 2011.
  - Lancaster, D., K. Smith, and A. Machiels, *Utilization of the EPRI Fuel Reactivity Depletion Benchmarks in PWR Spent Fuel Pool Criticality Analysis,* ICNC2011, Edinburgh (Scotland), September 2011.

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  - Lancaster, D., and A. Machiels, *Utilization of the EPRI Depletion Benchmarks for Burnup Credit Validation,* PHYSOR 2012, Oak Ridge (TN), April 2012.

Back-up Slides

Transportation of Spent High Burnup Fuel

- Key regulatory issue: maintaining sub-criticality under *accident* conditions
- NRC positions:
  - Burnup <45 GWD/MTU: normal assembly configuration
  - Burnup >45 GWD/MTU: fuel reconfiguration cannot be ruled out ➔ "moderator exclusion" or "analytical simulation" option
- Observations
  - High-burnup fuel burned to "design burnup" has low residual nuclear reactivity
  - Should significant reactivity remains ("under-burned"), normal configuration could be assumed
  - With burnup, as cladding properties ↘,nuclear reactivity ↘

Importance of a Centralized Accounting System

- ANSI 15-8, *Special Nuclear Material Control and Accounting Systems for Nuclear Power Plants,* provides reasonable guidelines to record, track, and verify F/A burnup in a centralized accounting system
- Core follow software provides accurate information of the burnup of fuel assemblies. Each spent F/A can be directly associated with its burnup history over multiple fuel cycles
- At any time before a spent fuel cask is shipped
  - F/A burnup and SNM content can be verified against in-core detector measurements and core follow calculations for reactor controls by F/A serial number.
  - Video of F/A serial numbers during cask loading provides ability to independently verify proper loading

Train Accident Initiating Events

Case Study Number	Case Study Initiating Event Description From EPRI Report 1016635	Point Estimate Frequency (Events/ Train-Mile)
1	All Train Accidents per Train-Mile (All Accidents, All Speeds, All Track Classes), 2000 - May 2006.	4.33E-06
2	Freight Train Accidents per Freight Train-Mile (All Accidents, All Speeds, All Track Classes), 2000 - May 2006.	2.67E-06
3	Freight Train Accidents per Freight Train-Mile (Accidents with Primary or Secondary Derailments, All Speeds, All Track Classes), 2000 - May 2006.	2.25E-06
4	Freight Train Accidents per Track Class 3+ Freight Train-Mile (using Table 2-4 of Ref. 8) with Speed ≥ 30 MPH, 2000 - May 2006.	6.51E-07
5	Freight Train Accidents per Freight Train-Mile (Accidents with HAZMAT Car Damage, All Speeds, All Track Classes), 2000 - May 2006.	3.06E-07
6	Freight Train Accidents per Freight Train-Mile (Accidents with HAZMAT Car Damage, ≥ 30 MPH, Track Class 3+), 2000 - May 2006.	8.45E-08
7	HAZMAT Freight Train Primary and Secondary Derailment Accidents per Track Class 4+ Freight Train-Mile (using Table 2-4 of Ref. 8) with Speed ≥ 60 MPH, 2000 - May 2006.	1.05E-08
8	Freight Train Primary and Secondary Derailment Accidents per Freight Train-Mile (Accidents with HAZMAT Car Damage, ≥ 60 MPH, Track Class 4+), 2000 - May 2006.	8.01E-09

United States Nuclear Regulatory Commission

Protecting People and the Environment

Presentation to the ACRS Full Committee – 597th Meeting

US-APWR Design Certification Application

Safety Evaluation Report with Open Items for Chapter 9, Auxiliary Systems

Jeffrey Ciocco
US-APWR Design Certification Lead Project Manager

September 6, 2012

Agenda

- US-APWR Design Certification licensing overview.
- Summary of the Chapter 9 Safety Evaluation Report (SER) with Open Items.

US-APWR Design Certification Review Schedule

TASK DESCRIPTION	COMPLETION DATE
Phase 1 – Preliminary Safety Evaluation Report (SER)	Completed
Phase 2 – SER with Open Items	November 2013
Phase 3 – ACRS Review of SER with Open Items	March 2014
Phase 4 – Advanced SER with No Open Items	August 2014
Phase 5 – ACRS Review of Advanced SER with No Open Items	October 2014
Phase 6 – Final SER with No Open Items	March 2015
Rulemaking	August 2015

Chapter 9 Auxiliary Systems SER with Open Items

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- Chapter 9, Auxiliary Systems, of the US-APWR DCD, contains:
  - The fuel storage and handling systems
  - The water systems
  - The process auxiliary systems
  - The air conditioning, heating, cooling, and ventilation systems, and
  - The other auxiliary systems, such as the fire protection program and the Gas Turbine Generator (GTG)

Chapter 9 Auxiliary Systems SER with Open Items (cont'd)

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- At the Sub-Committee meeting in March 2012, Staff presented the following Open Items.
- Essential Service Water System (RAI 915-6344) is now confirmatory – pending a change to the DCD by MHI.
- Component Cooling Water System (RAI 878-6200) is now confirmatory – the response is acceptable pending a DCD revision from MHI.
- Condensate Storage Facilities (RAI 863-6148) is now confirmatory - the response is acceptable pending a DCD revision from MHI.

Chapter 9 Auxiliary Systems SER with Open Items (cont'd)

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- Control Room Area Ventilation System and Engineered Safety Feature Ventilation System (RAI 883-6063, Question 30) is still an open item – staff is reviewing a recent response from MHI.
- Control Room Area Ventilation System (RAI 883-6063, Question 32) is still an open item – staff is waiting for a submittal from MHI.
- Questions?