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UNITED STATES NUCLEAR REGULATORY COMMISSION'S
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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604th MEETING

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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THURSDAY

MAY 9, 2013

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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 1:00 p.m., J. Sam Armijo, Chairman, presiding.

COMMITTEE MEMBERS:

J. SAM ARMIJO, Chairman

JOHN W. STETKAR, Vice Chairman

HAROLD B. RAY, Member-at-Large

SANJOY BANERJEE, Member

DENNIS C. BLEY, Member*

CHARLES H. BROWN, JR. Member

MICHAEL L. CORRADINI, Member

DANA A. POWERS, Member

COMMITTEE MEMBERS: (cont.)

JOY REMPE, Member

MICHAEL T. RYAN, Member

STEPHEN P. SCHULTZ, Member

WILLIAM J. SHACK, Member

GORDON R. SKILLMAN, Member

NRC STAFF PRESENT:

MARK L. BANKS, Designated Federal Official

DONALD CARLSON

EDWIN HACKETT

STEVE JONES

MICHAEL MAYFIELD

TIM McGINTY

MARK RUSSO

ALSO PRESENT:

DAVID ALBERSTEIN, Idaho National Laboratory

JIM KINSEY, Idaho National Laboratory

TOM O'CONNOR, Department of Energy

FINIS SOUTHWORTH, AREVA

*Present via telephone

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

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

(1:00 p.m.)

CHAIR ARMIJO: Good afternoon. The meeting will now come to order. This is the first day of the 104th Meeting of the Advisory Committee on Reactor Safeguards. During today's meeting, the Committee will consider the following, first, Next Generation Nuclear Plant key licensing issues; second, Generic Issue 189, Susceptibility of Ice Condenser and Mart III containers through early failure from hydrogen combustion during a severe accident; and, third, preparation of ACRS reports.

This meeting is being conducted in accordance with the provisions of the Federal Advisory Committee Act. Mr. Mark Banks is the Designated Federal Official for the initial portion of the meeting.

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

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.

The first briefing will be on NGNP. Dr. Bley is in New Mexico on the bridge line. And I will be chairing the briefing here. So I would now like to turn the briefing over to Mr. Tom O'Connor, the Department of Energy.

MEMBER REMPE: Mr. Chairman, I need to interrupt you.

CHAIR ARMIJO: Yes. Go ahead, Joy.

MEMBER REMPE: I do have some organizational conflicts of interest concerning this topic.

CHAIR ARMIJO: Okay. Thank you very much.

With that, Tom.

MR. O'CONNOR: Good afternoon. By way of introduction, I'm the Director of the Office of Advanced Reactor Technologies. Since 2005, I've been responsible for the Department's Generation IV Reactor Research and Development Programs. So that addresses all of the four concepts, SFRs, LFRs and of course the NGNP program.

The NGNP program has its orientations in the Energy Policy Act of 2005 and not only did it specify what the project organization and management structure should look like, but it also specified the Department of Energy and the Nuclear Regulatory Commission should work aggressively towards identifying and laying out licensing framework and strategy for this.

The report depicted on the slide reflects the first fruits of that interaction, the 2008 Report to Congress, which identified the licensing strategy. And the licensing strategy is relative to an admonishment by Congress to develop this which is to ensure that we can develop a design based on a firmly established licensing framework as well be able to make the kinds of economic decisions with a solid design that would determine whether or not the reactors had the commercial viability necessary.

I think over the past eight years we have worked quite well together with the Nuclear Regulatory Commission not only in developing this strategy, but also in developing a number of research and development activities and collaborated on a number of experiments.

In terms of the key pieces of the strategy report, it identified many of the same topics that were identified in earlier licensing efforts related to high-temperature gas-cooled reactors. Those associated with the earlier MHTGR and NPR data as well as the work that was done in conjunction with the Exelon's efforts to license a pebble bed reactor here in the United States.

Following the licensing strategy report, it was delivered to Congress in the 2008 time period. We had a number of efforts ongoing with the NRC with the development of a number of White Papers and subsequent assessment reports that also identified the four major key areas. And last year we got to a point where we really needed to drive home resolution of the four major positions that had been in essence dogging the high temperature gas reactor space beginning with the days of the MHTGR and NPR.

Right now, we continue to devote our research and development efforts on some of the resolution of some of the longstanding issues principally associated with the fuels work and the graphite. And I think that we're making a tremendous amount of progress and inroads on that.

I think in terms of the work that was done with the NRC we've also come to a good understanding of what our issues are and what the path forward on it needs to be. I would say though that at this point we still have some uncertainty associated with the determination of design basis accidents that appears to go beyond what the previous Commission policy on the identification of those scenarios would be. Hopefully, we can with your help get to a closer resolution of that, a resolution that will help us establish the licensing framework that will allow us to move forward with the design efforts and ultimately the commercialization of this technology.

That's the end of my opening remarks. I'd be happy to entertain any questions that you might have.

CHAIR ARMIJO: Your issue is with the process for determining these DBAs or is it more than that?

MR. O'CONNOR: It's associated with when we -- The path that's proposed identifies a number of deterministic approaches that are influenced by the probability risk advisement. But it's at the end of that that it seems at least based on recent discussions that there will be other yet to be determined accidents that need to be taken into consideration, things that are beyond what we would have considered as a part of the normal design and safety iteration process.

And it's that uncertainty that precludes us from really understand what is going to be expected of the design.

MEMBER CORRADINI: Tom, is the uncertainty based in the fact that the design is yet to be completed or is the uncertainty based that you're not sure what staff is going to ask of you given that the design is complete enough? What I'm trying to say is that they said you might have to consider X and you say X really isn't in the PRA. So why is X even out there as a possible deterministic bound.

Or is it they're saying from your perspective that we want to see more of the design. And until we see more of the design, we can't tell you what X is.

MR. O'CONNOR: More of the former. We have to recognize that, yes, there are some designs out there. But they have not progressed to a point where you would do the kind of rigorous PRA analysis that would be necessary. Our concern is that once we have done the design and done the PRA and made the adjustments to ensure that we keep all of our accidents within the acceptable limits that when presented then we would receive additional "You need to go and look at this or you need to go and look at that." And that's where our uncertainty is.

And I would like to ask if -- That's what the subject of Jim's presentation is.

MEMBER CORRADINI: Okay. I just wanted to make sure --

MEMBER REMPE: But if they came in with a small or you came in with a small nodular PWR and IPWR do you anticipate you'd have the same problem with the staff from these interactions?

MR. O'CONNOR: Not having focused on the light water community I'm not going to go there.

MEMBER CORRADINI: Smart move.

MR. O'CONNOR: The bottom line for me is that I need to have a framework that's well laid out. It's not a moving target. It allows me to run through my design iterations and based on the analysis that I'm doing to be able to finish and finalize my design. And I don't want to find myself having to go back and rework my design because of additional requirements.

MEMBER RAY: Tom, let me turn Joy's question around. Do you think the present situation is unique to the NGNP that will be discussed here later or is it more indicative of any reactor of this same type coming down the path that it would come down being not a water reactor for example? In other words, is it a process issue or is it specific to the NGNP itself?

MR. O'CONNOR: I would be inclined to say that it would be something that other advanced reactors have to contend with.

MEMBER SHACK: But why are you surprised? I mean the NGNP DOE licensing agreement says you're going to use Option 2 which says you're going to have deterministic engineering judgment supplemented by, complimented by, PRAs. So it actually gives the weight to the engineering judgment, the deterministic analysis. I mean it sounds like you're coming in with Option 3 or Option 3 on steroids.

MR. O'CONNOR: Well, first, I don't want to bog down in Option 2 or Option 3. But I want to point to exactly how you framed it and that is first you take your design and look deterministically to make your engineering judgments to do your first set of examinations. And then based on those determinations you will overlay PRA on top of it. And that should be the end of it.

Shouldn't be coming back after that and saying "Well, I don't like the answers that you got. You need to go and pick this thing or pick that thing" which drags you in order to respond to that incredible event to have to reengineer and redesign your whole plan.

MEMBER SHACK: So propose the deterministic one right up front and you don't like it.

MR. KINSEY: I think this will be more clear from the other --

MEMBER RAY: But that at least would be different.

CHAIR ARMIJO: Yes, that would be different. You'd know what you're working with.

MEMBER RAY: But that's the point is if a deterministic event that they didn't like that would be different than the situation they're in now.

MR. O'CONNOR: The PRA in that case would show that that's not a credible event and push outside. If it is a credible event and does have the kinds of probabilities that warrant addressing, then that's within the realm of the design cycle.

MEMBER CORRADINI: If I may just take one more minute since somebody used to be sitting in this spot that I remember quizzing him when we were doing a letter for the licensing strategy. And if I went back to the transcripts, I think we ended up with kind of like a two prime. It wasn't two and it wasn't three, but it was more towards two than it was towards three. So it was -- I hate to use the word mushy, but it was a bit grayer than clearly two or three.

I remember Commissions Apostolakis asking about this because he wanted to link this to a testing of the technology nuclear framework. I just want to make sure we've got the sense of it as we were coming out of the framework discussion. That's all.

CHAIR ARMIJO: We will hear examples of particular kinds of issues that you're concerned about. Okay. All right. Thank you.

MR. O'CONNOR: To facilitate Jim's presentation I'm going to step back and rely on some of the other members of Jim's team to sit up here at the front table.

CHAIR ARMIJO: Okay. Thank you.

MR. KINSEY: Good afternoon. My name is Jim Kinsey. I'm the Licensing Regulatory Affairs Director for the NGNP project and the work at the Idaho National Laboratory. The other folks here at the table again work on our team at INL, Mark Holbrook, David Alberstein and Fred Silady.

I wanted to also confirm we were planning to have one or two folks on the line as well. Is David Hanson on the line?

MEMBER CORRADINI: I think they are on mute.

MR. KINSEY: We were expecting both David Petty and David Hanson from the team on the line.

CHAIR ARMIJO: Let's see if we can get this unmuted so they can confirm.

MR. KINSEY: We can move along. The basic structure, we've got about ten slides or so here. I think we can go through those pretty quickly. The basic structure is an overview slide here at the beginning, a couple of overview slides near the end and the middle four or five slides are all around this topic that Mr. O'Connor mentioned that has to do with design basis accidents.

I think we had some dialogue on this topic in the last subcommittee meeting. So the purpose today was just to do remind folks of that those particular processes are and just again summarize what our questions or areas of uncertainty are.

CHAIR ARMIJO: Jim, if you want to check if your people are on the phone.

MR. KINSEY: Sure. Is David Petty on the line?

MR. PETTY: I'm here.

MR. KINSEY: Okay. And how about David

Hanson?

MR. HANSON: I'm here as well.

MR. KINSEY: Okay. And just so you know if a question comes up where we need your help, I think the system will may be on mute. So it may take a moment to get you back online.

MR. HANSON: I've been on a mute button my entire life.

MR. KINSEY: Okay.

CHAIR ARMIJO: Okay. Go ahead.

MR. KINSEY: So just a very brief overview of the safety and design approach for the NGNP and the modular HTGR arrangement. It's our intention and our design goal to meet all of the NRC's offsite dose requirements and the EPA protective action guidelines at the exclusionary boundary which we define for purposes of the project to be in the range of about 400 meters from the reactor center line.

The reactor designs and our licensing strategy intended to be responsive to the advance reactor policy statement which is associated with coming up with designs that are highly reliable, less complex, lower plant response time, simplified features and maintaining considerable defense in depth.

We've had dialogue in the past about functional containment arrangement. It consists of multiple concentric barriers. It's nominally five barriers I just see listed there. Three of the five are associated with the particle fuel configuration. And then those are also supported by the helium pressure boundary and reactor building.

And the key focus here or the emphasis is on retaining the radionuclides at their source in the particle fuel. Three key pieces of that intention are the passive heat removal process, a process we have through our reactor cavity cooling system, control of heat generation and that occurs through the negative reactivity temperature coefficient and redundant sets of shutdown systems, and the control of chemical attack or oxidation of the graphite. And we control that by the use of a nonreactive coolant and then configuring the plan in such a way that it's very difficult for moisture or air to ingress and be in a sustained ingress arrangement or situation.

So again the next five slides or so, Dr. Corradini, kind of get back to trying to answer or clarify your questions and some of the other members questions around whether this is a process issue or an HTGR or NGNP specific kind of a topic. I'll try and step through those. Feel free to answer questions along the way.

So in our overall event selection process we start out by gathering up all of the applicable regulatory criteria. We pull those into a group that we refer to as the top level regulatory criteria. Those tend to be off-site dose-based and they all are deterministically developed. So those again come from the NRC's regulations which are coming from a deterministic background.

Then as we begin the design in the early parts of the licensing process but primarily the design, we select a series of events deterministically based on a number of inputs. And one of those primary inputs is past experience or past effort that's occurred within the HTGR community. So make those initial selections. And then as the design progresses as envisioned in the licensing strategy we then embellish or enhance that vision of those deterministic events by including risk insights. And again as the design develops, the community develop the PRA and take a second look at the events that we've selected and typically add to or modify it as the process progresses.

That results in a series of event types.

We'll look at those on an F-C curve in a moment. But there are essentially our anticipated events, design basis events, but beyond design basis events and then our design basis accidents.

We feel that that process is pretty comprehensive and provides a soup-to-nuts approach that looks at all event sequences and takes them essentially out to completion except in some cases where we group some of those sequences to facilitate getting to the results.

MEMBER SKILLMAN: Jim, would you back up one slide please?

MR. KINSEY: Sure.

MEMBER SKILLMAN: The last sentence of your third bullet, Chapter 15 events derive from DBEs with only safety related SSCs. That sounds like a clever exclusion comment. What are you really communicating?

MR. KINSEY: It's not intended to sound like a clever exclusion. It's actually a highly conservative deterministic portion of our process. If we could go -- I'll get to some examples of how that works in a couple of slides. If we could come to the question, then. I think if you see it in a picture I think it will be more clear.

MEMBER SKILLMAN: But what I'm really wondering is if you can credit other equipment or if you were limited to only that equipment.

MR. KINSEY: I'm sorry. With design basis accidents, we limit the plants response to only the safety related accidents. I'm sorry. I misunderstood your question.

MEMBER SKILLMAN: Thank you.

MR. KINSEY: Next slide. I think we've covered the frequency-consequence curve concept a number of times in the past. We've had a lot of good dialogue with the staff over this concept in our past interactions.

A couple of things I wanted to point out without getting into all of the detail is we've come to agreement with the staff on the vertical events sequence frequency portion of the scale that the cutoffs we've established for each of the three event types, the anticipated events, the DBEs and the BDBEs, overlaid are in the right place. We've also come to agreement with the staff that we've adequately and correctly reflected the regulatory requirements that apply to each of those regions. And you'll see those on the curve that's going down the right side there. And those are primarily from Part 20, from 50.34 and from the quantitative health objectives.

So at this point we understand that the staff believes or agrees that this depiction of both the requirements and our event types is reasonably and accurately reflected.

CHAIR ARMIJO: Jim, you don't put the design basis accidents on this chart.

MR. KINSEY: That's coming.

CHAIR ARMIJO: That's coming. Okay.

MR. KINSEY: Next slide. What we're going to do in the next two slides is describe how design basis accidents are derived. And then the next slide after this one will be a picture from the MHTRG era. And we'll talk through some examples there to make sure that this process is correct.

So again, Mr. Skillman, getting back to your question, when we develop the series of licensing basis events that exist, all of the ones that end up in that middle band on the curve which are the design basis events are then reevaluated considering or assuming that only the safety related structures, systems and components are available and respond. And we'll see what the effect of that is on the next chart.

Again, those are selected out of that

design basis event region. And when we make that deterministic decision to have only safety related material responding or SSEs responding it tends to drive as you could expect it the frequency of those events down into the lower regions, either the BDBE region or below. And you'll see that in the next example.

When we evaluate the consequences of DBAs we do that with a conservative upper bound analysis, a 95 percent analysis, which is consistent with the existing fleet as best I know. And we also wanted to make the point that our DBAs are not derived from the next region down which is the BDBE region. We apply again consistent with regulatory practice that all quantitative health objections, the QHOs, to that region. That's how we go about defining what the DBAs are.

If you move onto the next chart --

VICE CHAIR STETKAR: The second bullet there, I've always had problems. Maybe you can help me again. Why would the frequency of some DBAs become smaller as a result of assumed failures for things that I've taken credit for to get the frequency of those sequences in the DBE, design basis event, category? It would seem that the frequencies of some beyond design basis event sequences would increase to the DBE frequency range if I had failures of the nonsafety related stuff that I did not have failure of when they were in the BDBE range if that makes any sense. In other words, if you go to the next.

MR. KINSEY: If I go to the next one, I'll maybe talk through that a little bit.

VICE CHAIR STETKAR: Okay. I want to understand why things are going down.

MR. KINSEY: I'll take a first stab at that and I may ask for some help from our experts.

VICE CHAIR STETKAR: There we go. You need to stay by a microphone and use the mouse.

MR. KINSEY: Okay.

VICE CHAIR STETKAR: Because otherwise you're not on the record.

MR. ALBERSTEIN: Your mouse manager is here.

MR. KINSEY: Okay. Let me just make some key points.

MR. ALBERSTEIN: The mouse is wireless. That's the range of the mouse.

MR. KINSEY: Thank you. The first thing and this is related to some questions from past sessions. The first thing I wanted to point out is for all of our event sequences and I'll use the DBA 10 as an example, we look at an uncertainty band around both the consequence and the horizontal axis on the frequency of the requests. So we evaluate that uncertainly for each event.

The next point that I'll make is and this by the way if for an MHTRG plant facility that consisted of four reactor models. The next thing that we do within this process is we identify the series of design basis events. And you can see those sort of clustered around here with a couple of others in this region.

We identify those design basis events. We've done the uncertainty analysis around them previously. And now we make the assumption that for each of those events only the safety related components would respond.

So, Dr. Stetkar, as I understand it and to get to your question, when you reduce the number of components that would respond to a particular event, that response sequence would then be less likely to occur than if everything responded.

VICE CHAIR STETKAR: If you're assuming that everything that you respond is guaranteed to be successful. But if I have two things that can fail versus three things that could fail, failure of three things is generally less likely than failure of two things.

So if I take away that third thing and say it's guaranteed to fail, the likelihood that two things can fail is higher than the likelihood of three things. If I take away that third thing the frequency of that sequence ought to increase, not decrease, unless I'm assuming that the two things that were --

MEMBER BLEY: No.

VICE CHAIR STETKAR: Hold on a second, Dennis. Unless I assume that the frequency of the two things that are left is either improves or I'm assuming that they're guaranteed to be success.

Sorry. I just wanted to finish that.

MR. SILADY: My name is Fred Silady. And we had a slide that unfortunately is not in the backups here today that we presented in the January subcommittee meeting. And that slide showed a mini abbreviated tree. And it would have a DBE example in which the entire plant is responding. And it would have three things for heat removal as an example, the heat transport system, the shutdown and cooling system and then the last passive reactor cavity cooling system.

And just for talking purposes, let's say that that particular DBE with the entire plant responding is smack in the middle of the DBE region. So it had the entire plant responding. And it was probably 90 percent chance that one of those first two systems, each of them, are available in that particular sequence.

Now the deterministic step is to be consistent with Chapter 15 to be able to fit into the regulatory mold here that we're not going to have that heat transport system or that shutdown cooling system, those first two systems and everything in the chain out to the ultimate heat sink be in the sequence. So we're out of frequency space. This is just a deterministic assumption.

But if we were to ask where in the tree would that sequence have been, you could go look for it somewhere. It's much less likely that it's a sequence. So that DBA if you were to try to plot it on an F-C chart is going to be two orders of magnitude lower, 90 percent and 90 percent, because all of these three things were independent and so on.

Does that help?

MEMBER BLEY: No. This is Dennis. Let's go back to the --

VICE CHAIR STETKAR: Dennis, hold on. You're really mushy. So if you can help the audio.

MEMBER BLEY: Is this any better?

VICE CHAIR STETKAR: Yes, that's much better. But I don't like where you're going.

CHAIR ARMIJO: Keep going, Dennis.

MEMBER BLEY: I forgot where I was. It sounds like you'd go look for that sequence. That sequence includes those other two systems.

VICE CHAIR STETKAR: Yes, you still have three things there.

MEMBER BLEY: Yes. And when you're only accounting for the safety systems, those other systems don't exist. Protectively, they're guaranteed fail.

VICE CHAIR STETKAR: No, no. I'm not looking for the sequence that says I guarantee them fail and I lock them out. I'm looking for the sequence that they failed either randomly or dependently. That's what drives the frequency down.

MEMBER BLEY: Yes, that would. Assuming they could get you out of trouble. So you're not just relying on the safety system. Probably it's easier for him to talk to.

VICE CHAIR STETKAR: In one sense, I can kind of understand what they're trying to say, but it doesn't make any sense in the way you think about risk. They're trying to say the likelihood that those non-safety systems are absolutely guaranteed failed is really small.

MEMBER BLEY: That's true.

VICE CHAIR STETKAR: And that's true. And in that sense the likelihood of that particular sequence with those things guaranteed to be failed is small, the probability that they're guaranteed to be failed. That's I think the way they're trying to think about it.

MEMBER BLEY: I think that's right. But in the traditional sense.

VICE CHAIR STETKAR: But in the traditional sense, it doesn't make any sense to --

MR. SILADY: Explain to me -- sorry for interrupting. But explain to me if I have a plant with those three systems. You're describing to me a plant that only has safety related things and that plant never exists.

VICE CHAIR STETKAR: But, see, you're claiming. You have to be careful about the differences between a systematic, quantitative risk assessment and qualitative claims about what you're going to call design basis events. You are creating the construct that only safety related systems you can take credit for. You're creating that construct. The risk assessment --

MR. SILADY: Then Chapter 15. I'd love to --

VICE CHAIR STETKAR: And that is also a construct. Yes, that is a construct. But you're creating that construct by presuming that only safety related systems can participate. The risk assessment which originally partitioned all of these sequences in this eight order of magnitude or nine orders of magnitude frequency space didn't make that presumption.

MR. SILADY: No.

VICE CHAIR STETKAR: Making the presumption that only safety related systems are available can only increase what possibly remain the same the frequency of sequences from the risk assessment because you're removing things that could have made things better.

MR. SILADY: I think this is as a result of just looking at it as if you had a plant that only had safety related systems.

MEMBER BLEY: Yes.

MR. SILADY: And we're not looking at it

as if we're going to build a plant. I'm looking for the realistic risk. What's my actual frequency and consequences coming from the sequence I'm going to put in Chapter 15.

VICE CHAIR STETKAR: But you're selecting your presumed scope of that from a specific frequency range that has a population of a fixed set of sequences. You're not looking in the beyond the design basis event frequency range.

Suppose I had 11 systems in the plant, ten of them I'm calling non safety related and I've only got one that's safety related. And I do a risk assessment and I take credit in that type of work. I quantify all 11 of those systems. And as a result of that I have a sequence with a frequency of 10^{-7} beyond design basis. It's even below your less than 5 times 10^{-7} range.

MR. SILADY: Right.

VICE CHAIR STETKAR: If I only take credit for the safety related system, is the frequency of that sequence going to be higher or lower than 10^{-7}?

MR. SILADY: That's not the process that we're proposing here, but yes.

VICE CHAIR STETKAR: That's not the process.

MR. SILADY: But I understand where that would go.

VICE CHAIR STETKAR: It's going to be much higher.

MR. SILADY: Yes. Sure.

MEMBER BLEY: Can I weigh in again? I'd like to weigh in again. The discussion now clarifies the two things that's going on. I think the problem John and I have had is that the language of only taking advantage of the safety system, the traditional approach, which assumes those other systems are not there. Once they've actually called these PDAs now the frequencies are up and down, but they are PDAs. And they're going to have to analyze the details that PDA requires.

MR. SILADY: Absolutely.

VICE CHAIR STETKAR: And that's correct.

MEMBER BLEY: So I think it's more a matter of semantics for it.

MEMBER CORRADINI: I think it is semantics. I don't think it's substance.

VICE CHAIR STETKAR: I don't think it is substantive. But I think they have to be very, very careful about how you present this saying that when we define these as design basis events -- Your words say when we define them design basis events and take credit only for the safety systems, their frequency may decrease. And that second part of that sentence is creating this source of confusion.

MR. SILADY: Okay. I'll think about that little more, but I understand.

MR. KINSEY: So I guess carrying on with the example you can see that for the design basis events that are again clustered in that design basis event frequency region when we make this assumption and move them into design basis accident space, we can see that they move a couple over here with limited or zero consequence. Others move well down into frequency space down actually below 5 times 10^{-7} cutoff.

And I'll point out this note in the margin here that there are additional DBAs that aren't reflected on the chart that go even below 10^{-8} from that DBA, or excuse me, DBE set that was evaluated for MHTGR.

MR. KINSEY: Any other questions about it?

MEMBER BLEY: Yes. Could I jump back in?

MR. KINSEY: Sure.

MEMBER BLEY: I've enjoyed this conversation. We do have the problem of what people might interpret from the word. The positive side of this is that we're really shining a light on the conservatism that exists from the DBAs and that's true currently as well. So that's an interesting thing.

MR. KINSEY: I'd like to go onto the next slide.

MEMBER SHACK: Let me just make one comment. Again, the whole discussion assumes that you know the frequencies and uncertainties of all these sequences. So again that's a given in this approach. And suppose I say I don't really believe your frequency or your uncertainty for those beyond design basis events and I want to make that into a DBA.

MR. KINSEY: I guess I understand that question and that's one of the items when you're asking some questions of Mr. O'Connor. That's one which I guess requires additional design detail to get into that dialogue.

MEMBER CORRADINI: Can I just follow on with that because I thought Bill was going to go somewhere else. But what I was going to ask is if it was prismatic or pebble, does that design detail move these dots around a lot, a little or yet to be determined?

MEMBER SHACK: Well, even after I know all the design detail, I still have to believe the frequencies and uncertainties. And there may be mechanistic processes that are going on here that I haven't -- I'm not sure even for a light water reactor how confident I am.

MR. KINSEY: But to answer your question, the purpose here was to illustrate the process and this is one example for the MHTGR.

MEMBER SHACK: Okay.

MR. KINSEY: Certainly for individual designs, there are going to be different dots in different places. This was to describe the construct.

VICE CHAIR STETKAR: But, Jim, if we're going to talk about that notion since Bill brought it up and if you want to postpone this, we can do that. But that concern about selecting another scenario and saying you need to treat this as a design basis event, you could do that either because that scenario is not in PRA. It's a new scenario, somebody dreams up the Godzilla scenario. Or you could do it because it's a scenario that's in the PRA but you just don't believe the numbers.

MR. KINSEY: Right.

VICE CHAIR STETKAR: I mean both of those are constructs.

MEMBER SHACK: The Godzilla one I would just put into the PRA.

VICE CHAIR STETKAR: Okay. And that's an important distinction because as the people conjure new scenarios in principle there's nothing preventing you from adding those scenarios to the PRA if they're not already in there and quantifying them on this scale consistently and evaluating where they're at. Maybe you did miss something.

MEMBER SHACK: Sure.

VICE CHAIR STETKAR: And it's legitimate to add it to the PRA. So that's one of these issues about additional scenarios.

MEMBER SHACK: I don't look at that as an issue. That's just a --

VICE CHAIR STETKAR: I don't either, but we've had some discussion about it. And the preliminary discussions seem to focus a bit in that direction rather than in your direction. That's why I wanted to bring it up here.

MEMBER RAY: John, can I ask a question here? Excuse me, John. In what you and Bill are talking back and forth about I guess I'm thinking and trying to answer the question in my mind about isn't what you're saying always going to be true. Or is it something that exists because there isn't enough detail now and would go away if I had more detail? So be resolved sort of both.

VICE CHAIR STETKAR: But I'm presuming -- Let's presume you have a perfect knowledge of the design. Let's just presume that from the beginning. Someone can postulate the Godzilla scenario and say "You didn't account for this in your PRA."

MEMBER RAY: That's right.

VICE CHAIR STETKAR: So that issue at that level.

MEMBER RAY: I'm trying to say, "Yes, that's true. I agree with you." But what I think is more at issue here is at what point do I have enough information to satisfy the questions that I can't answer without that information. And it's necessary in order for me to have -- I don't want to say issue a design certification. But it's necessary for me to have done a complete job of looking at the licensing basis.

VICE CHAIR STETKAR: Okay. Licensing events. But still let's take the Godzilla scenario. I didn't quantify it in the PRA. I don't know exactly what that is. Maybe I'm not sure what phenomena are going on.

I can still quantify that in the context of a PRA. I have uncertainties. I have scenarios. I can evaluate the frequency, uncertainty and consequences because I have that tool available. The uncertainties might be large. But sometimes large uncertainties don't make a difference. That may be true. But if they do then I ought to --

Now, Bill, your construct of something that's already in the PRA and I don't have confidence about the frequencies or the uncertainties ought to be addressed also within the PRA. Now the people alleging the fact that I haven't quantified the frequency on the uncertainty just can't say we don't know anything and therefore you have to assume this is a design basis accident because that is irresponsible.

They must provide an argument that said "We believe based on the following state of knowledge about the design or the phenomena or understanding that the range of uncertainty is between X and Y." And if they can't do that, they ought not to be just dreaming new things.

MEMBER RAY: I think the things that's --

VICE CHAIR STETKAR: Once you do that, you can put it in the --

MEMBER RAY: The question is --

VICE CHAIR STETKAR: This may be a discussion for later but ---

MEMBER RAY: But the issue at hand anyway is are there things that I might not be able to do as you described very well because I don't know enough. In other words, there are things that I can't recognize without knowing more.

MEMBER SHACK: He can always quantify uncertainty.

VICE CHAIR STETKAR: I can.

MEMBER SHACK: Some of us believe that we can.

MEMBER RAY: Like I said, we ought to go on.

VICE CHAIR STETKAR: But the reason I wanted to bring this up in the context of -- You gave me an opening, Bill. Because I understood the initial discussion, it was focusing more on the scenarios that -- my Godzilla scenario -- have not been quantified that someone divines. And I wanted to understand a little bit from your perspective. Is that correct? Or is it more focused -- Is your angst more focused on sort of Bill's issue?

MEMBER BLEY: I would still like to get in on this.

VICE CHAIR STETKAR: Yes.

MEMBER BLEY: This argument, this is something we've been talking about on the committee. And it simplifies the picture. So I'm kind of full of scenarios. Of course, if there is a new scenario, it can be added.

Bill's point and Harold's is a different way to look at the point as far as I'm concerned. Once you've done the best you can, there still might not be enough time for them in what's been done to accept it as is and that's when the structural side of this argument comes in. And we have something added to defense in depth to protect against our uncertainty of this process

We're never going to get away from that. And I think that side of this thing is always going to be here when you can't make the case that should really cover it. Conventionally, you might need some kind of defense in depth perspective against it.

MEMBER RAY: And does that go away, Dennis, at some point when I get more and more detail? Or is it just a reality that always exists?

MEMBER BLEY: If I ever think I have really covered it, yeah. There will be issues where people can point out that the experiments we have done have some flaws. There are other things that we haven't fully considered. In principle, eventually you get rid of that. In fact, I'm not sure you really do. And if you look back at Bill's technology neutral framework, they always kept aside for the structurist point of view to protect against those uncertainties.

MEMBER RAY: Okay.

MR. KINSEY: So I'd like to get back to a couple of questions you asked just to be sure that our angst with the direction it appears we're going come from. If you use the Godzilla or some other newly defined event sequences as an example, our concern is that as we understand the draft guidance from the staff that they would propose that events like that could be identified in the future and would be just directly added to our list of required DBAs.

Our preference and what we think the right thing to do is if we find that our event identification process wasn't complete and there is in fact a new different event sequence that we need to consider, we certainly would do that. But we think we should put it into the process and turn the crank and see what comes out and then deal with the result as necessary.

I think an example of that without getting into a lot of detail is from the MHTGR review. I believe the staff did identify an additional event that they felt should be evaluated in that whole suite of event sequences.

It was evaluated by General Atomics at the time and you see down towards the middle center of this chart there's an Appendix G-2 event there. That was the outcome of the result of that evaluation.

So the key for us is in this feedback. We're certainly always open to evaluating additional in that sequence if there is something that appears to having missed something. We just are very uncomfortable with just adding that event to the DBAs. That's the issue.

VICE CHAIR STETKAR: Just arbitrarily designate that event as another DBA.

MR. KINSEY: As Mr. O'Connor said, that gives you sort of a bottomless pit of event sequence frequency and you don't really ever know what's going to be required until it's required.

MEMBER CORRADINI: So can I connect that comment to John's description? The way I hear I would interpret what you said is that if something is offered to you you would say we have to evaluate where it sits within this construct. And if it sits too far down in your opinion or too far over in some way or it's physically impossible because of the either experimentation or a combination of experimentation and analysis, it just shouldn't be there. That's kind of what I heard you say.

VICE CHAIR STETKAR: Yes. But at least you know, you have the knowledge, of where if it's in the framework of everything else.

MR. KINSEY: The focus on the construct of the framework.

MEMBER CORRADINI: But have I said it approximately?

MR. KINSEY: Yes, exactly.

CHAIR ARMIJO: While I think this would be an interesting discussion, I think we really have to keep moving along. We've got roughly about another hour and ten minutes to cover a lot of material.

MR. KINSEY: But I know we are past the en of our time. I think we should just wrap up because I think we've gone across the points.

CHAIR ARMIJO: Make the points you wanted to make.

MR. KINSEY: I just wanted to go back. Mark, if you could go back to the F-C curve. The first one. I'm sorry.

So there are two key points and these are reflected on the -- If you want to look at the hard copy of slide 14 at the same time. It's the summary of -- It's called "Summary of Findings." There are two primary areas of significant uncertainty and I guess a little bit of confusion.

The staff has proposed that additional design basis accidents would likely or could potentially need to come from two places. One would be picking an event that's currently in the BDBE range and calling a design basis accident. And then instead of applying the QHOs as its rule set, upgrading it and essentially causing the applicant to evaluate it against Part 50.34. So that's one issue or concern.

And then the second is the one that we just talked about and that's coming up with a new deterministically selected sequence and just adding it to the list of DBAs without putting it through the process. So those are the two things that we really appreciate some additional clarification on as these documents are developed.

MEMBER CORRADINI: It would effect the other slides we haven't gotten to in terms of source term, etc., etc.

MR. KINSEY: It may effect everything.

MEMBER CORRADINI: That's what I thought. Thanks.

MR. KINSEY: And again that summary slide 14 points out those sub-bullets there at the bottom which are the two things that I just mentioned.

And the other thing I guess we threw in as an example is on the very last slide on this general topic from the draft safety evaluation of the MHTGR. The staff seems to have come to the conclusion that everyone had done a pretty thorough review of all the event sequence types and they couldn't really think of any others at that point.

That's not to say that some couldn't come out in the future. But it doesn't to us that they should if there are any new ones identify that they should directly go on to the DBA list which would go the process as it was done back in that day with that example. I'm not sure. That's all I have.

CHAIR ARMIJO: Any other questions? Comments? Dennis, anything else?

(No response.)

Okay. Let's move on then.

MR. KINSEY: Thank you.

CHAIR ARMIJO: And Staff?

DR. CARLSON: Okay. Mike Mayfield is on

the agenda to give some opening remarks.

CHAIR ARMIJO: Go ahead.

MR. MAYFIELD: Okay. I just wanted to say a couple of things. First of all, I really enjoyed previous discussion. It took me back about 25 years because we've been having discussions for at least that long. I wanted to characterize what Don's going to present this afternoon in terms of what it is and what it isn't.

Let me start out by saying what it isn't. It is not a licensing review of a high temperature gas coolant reactor. We have been having dialogue about policy issues for a good long while, at least 25 years. Tom O'Connor and I talked about what do we do with these things absent a specific design coming forward absent more specific technology. What can we do?

So we agreed about a year and a half, two years, ago that we would do what we could to move forward with some key policy issues and Tom identified those four areas. And Don is going to talk about them in more detail this afternoon.

Going into this, I don't think Tom or I, either one, thought we would come to absolute agreement on without question this is how you address these policy issues. But could we move the dialogue forward from the great religious arguments we were having? We kind of wanted to get beyond the point where the staff is referred to as Godzilla. But hopefully we've gotten there. But perhaps not.

I do think that we can make further progress on these absent a complete design. Tom was expressing some concern about having invested in a complete design, the Staff doing that with some additional events to be considered.

We do see this and we've seen it with the preapplication discussions on the large light water reactors. And we absolutely are seeing it on the preapplication discussions with the small modular reactors where a design is reasonably complete. But through discussions with the staff the designers are going back dealing with some additional considerations, dealing with some additional issues. And they're not having to completely redo the entire design.

I think that preapplication discussion on these as we move forward can avoid the doomsday scenario where a designer or vendor has spent a lot of time and money developing a complete design and then we stand down on its head. So I think the preapplication discussions are designed to avoid that.

And that's where we would look to get once we have a specific design, specific technology, beyond just a generic, high temperature gas reactors. Something more specific I think we can and would expect to make further progress, potentially getting this to the point of where we can dress up some of these things and make policy proposals to the Commissioners and let them react to them.

Absent more specifics, we felt like this was about as far as we could go. With that bit of introduction, Mr. Chairman, I would like to turn back to Dr. Carlson to present the staff's assessment.

CHAIR ARMIJO: Don, go ahead.

DR. CARLSON: Okay. My tent says I'm NRR but I'm really NRO. And so my name is Don Carlson. And I am the lead PM for NGNP. I came before the subcommittee and I was assisted by some excellent presentations from Jim Shea, Arlon Costa, Dr. Tom Boyle and Jonathan DeGange. But given the little bit of time I'm going to handle the full presentation myself today. But they may want to come to the microphone to elaborate certain comments or questions you may have.

I would also like to acknowledge there

have been a number of people involved in this activity over the last few years. Sud Basu from the Office of Research has been involved from the very beginning and has been a major contributor through activities.

We also have Mark Caruso in the room who has provided some excellent risk insights and Michelle Hart. Joe Williams did some very good leadership of the preapplication activities a year ago or two years ago. And so a lot of that is due to the contributions of those other participants. But Jim, Arlon, Tom and Jonathan really did a lot of work to bring it down to the wire the last year or so.

I would also like to acknowledge that we have a lot of help in our fuel qualification from Dr. Mike Konya who is a true expert. I believe he's listening in today and I want to express our appreciation. He really is a recognized expert on TRISO fuel and he was a great help.

A little bit of the project history and status. As you know, the project was created by the Energy Policy Act of 2005. DOE was charged to demonstrate high temperature reactor and they chose a modular high-temperature gas-cooled reactor (HTGR) for co-generating electricity and process heat in the NRC licensing authority over the prototype plant.

We've had a number of majority preapplication activities to date. I'd like to note that back in 2007 we had a good start with DOE and NRC conducting a joint Phenomena Identification and Ranking Tables (PIRT) process. It had five PIRTs. And Dr. Corradini was on one of the PIRT panels for accident analysis.

CHAIR ARMIJO: And don't forget Dr. Powers.

DR. CARLSON: And Dr. Powers was on the panel for fission product and dose.

MEMBER CORRADINI: He's in his normal location.

DR. CARLSON: I don't see him here today.

Those were very good PIRT exercises. And I think they helped shape a lot of things that have been going on since. And I would also like to acknowledge that Dr. Powers and Dr. Petty participated in an NRC research PIRT in 2003 on TRISO fuel. That likewise was an excellent product and has helped us gain insights which we based our review on ever since.

So the next item that was very significant was our Joint Licensing Strategy Report to Congress. And we talked about the Option 2. And again the Option 2 framework was there were a spectrum of options. Option 1 was traditional, deterministic and Option 4 was risk-based and options two and three were between the two extremes.

And the draft DOE-NRC working group settled on Option 2 which is risk informed, performance-based approach using deterministic engineering judgments and complimented by PRA insights.

Since 2010, we've been focused on our assessment review of some DOE White Paper submittals to better define the option approach.

Then a year and a half ago, DOE's decision in a letter of Congress based on some NIAC recommendations -- and we have some NIAC members here -- DOE decided they would not proceed with NGNP design activities. But they would continue to focus on their R&D efforts and interactions with the NRC to develop a licensing framework. And they continued their efforts to establish a public-private partnership with NGNP Industry Alliance.

We've had a number of interactions and over the last year or so those consisted of -- We issued our preliminary assessment reports, Rev 0 of the White Papers. So one of them addresses fuel qualification and mechanistic source terms. The second one addressed the RIPB topics, defense-in-depth, licensing basis event selection and systems inspections and components classification.

At the same time we issued a letter to DOE that we agreed to continue focusing the effort on resolving these frame work issues under the key issue headings of licensing basis, source terms, functional containment performance and emergency preparedness. And those are the issues that have been highlighted in various forms in the Licensing Strategy Report to Congress of 2008 and in our preapplication activities for MHTGR going back 25 years. These kinds of issues have been highlighted for a long time.

Then on July 6 last year DOE clarified its approach to these key issues. We had a number of public meetings and conference calls through November of last year. And we did get two additional technical documents that provide clarification that we reviewed.

Then in January this year, there was a DOE information briefing of the subcommittee on NGNP activities.

And then last month we briefed the subcommittee a longer version of the presentation I'm giving today.

So what we have are three staff products that we're going to try to issue. They're now in draft form. The first one is we issued a summary report that basically responds to the specific request for feedback that we got in that July 6th letter from DOE on these four major issues.

And then we had updates. Rev 1 of the two assessment reports that were developed previously where we have additional staff participating in the review process and we have a higher level of management concurrence on those products, division level at this time. Ultimately, after we get ACRS' review and your comments in a letter, we will finalize the products and publicly issue them to DOE as attachments to a letter.

So at a very high level, our major conclusions are there are no obvious show stoppers here. They are proposed approaches to NGNP licensing issues which are responsive to NRC Advanced Reactor Policy Statement and then generally reasonable with a number of caveats. And at a high level, the caveats are the deterministic elements should be strengthened and better aligned with Option 2 as opposed to Option 3 which it seems to look like.

Technical uncertainties, there are technical uncertainties and we do believe that testing in the NGNP prototype under 10 CFR 50.43(e) will be necessary to supplement the technical understanding of fuel and core performance. And that is actually quite consistent with the Licensing Strategy Report to Congress.

CHAIR ARMIJO: Don, I would like to interrupt. This is an uncertainty that can only be resolved by testing of a prototype. Is that what I heard?

DR. CARLSON: Yes. The short answer is yes. You could try to address it by additional testing in the fuel program. But ultimately I don't think additional testing of the fuel program would reduce the scope of what you're talking about here.

CHAIR ARMIJO: How would you license that prototype if you can't --

DR. CARLSON: Well, we have provisions and the like in the regulation 10 CFR 50.43(e). So if you're relying on prototype testing to establish your safety or completeness of the defense of your safety basis then this allows the staff to impose additional requirements to protect the public and the workers during the testing period.

CHAIR ARMIJO: Okay. Could you give just one example of a particular type of test?

DR. CARLSON: An example will be in several slides later.

CHAIR ARMIJO: Okay.

MEMBER REMPE: Could you also elaborate a little bit more about the deterministic elements should be strengthened to better align with Option 2? Would you concur with what they indicated that the two issues were? And are you going to have to specify further and give us some specific examples?

DR. CARLSON: That's in a few slides.

MEMBER REMPE: Okay.

DR. CARLSON: Another conclusion that I think was worth highlighting is that we didn't do a lot of emergency preparedness approach, but we do feel that future interactions this early are important and they should be supported by specific information on the NGNP design of the site and co-located user facilities and that information should be provided by the site.

There are a number of qualifiers in all these conclusions. First of all, we considered everything in terms of relevant prior staff positions. And what we're saying here really is not inconsistent to marginally very consistent with the relevant prior staff positions, consideration of ACRS comments and

Commission policy direction.

And so I listed a few of the SECY papers from NGNP 20 years ago, PBMR ten years ago, NUREG-1860 which is the technology nuclear framework, the licensing strategy and a SECY paper that we wrote on 1860 a year and a half ago.

Staff feedback is advisory. So these are not regulatory decisions. The decisions will be based on a license application and related to the Commission policy direction.

Of course, the NGNP RIPB approach overlaps with the high level concepts being considered in other context like you would 1860, the NUREG 2150 which is the Apostolakis risk management report and the Fukushima NTTF Recommendation 1. So any changes to the framework presented from those activities per the report first reflect on our staff positions for NGNP and changed them.

Finally, there was discussion at the subcommittee meeting and at the January information briefing among the Committee members indicating that this may be applied in the technology neutral sense. We haven't looked at a technology neutral. DOE INF has presented to us only as it would apply to the NGHP modular HTGR design concepts and we have assessed it only that way.

So what is a modular HTGR design? I think you've become familiar with that. It was really a response to TMI. Until TMI, the HTGR community in Germany and in the U.S. were going to build ever larger HTGRs. I could show a slide like this that has the German HTGRs on that where instead of Peach Bottom we had ABR, Port St. Vrain. We had the THTR.

And instead of the large HTGR, it would be the PMP 3000. I was in Germany during 1978 to 1983 and I witnessed up close the mind change and in fact the first idea, the first paper, that gave us the modular HTGR design concept in 1981 from Germany. And in fact it was a very first collaboration in those days between the German and the General Atomics and Oak Ridge. And General Atomics followed suit with their concept of the modular HTGR.

So what happened after TMI, two things actually. About 1980 the Germans perfected the state of the art of TRISO fuel. And they established what people considered the gold standard of TRISO fuel. Really high performing/high quality TRISO fuel.

And then TMI said "Let's see what we can do to make this inherently safe." And so they basically said, "We don't want to need coolant to keep the fuel at safe temperatures." And so to do that instead of the PCRV, the pre-stress concrete reactor vessel, they went to a metallic vessel, put it in a passively cool cooling system. Heat kept the geometry nice and normal and slender. Reduced the power density. So you don't need coolant to keep fuel temperatures in the safe region.

I'm starting now with the licensing basis event selection. The licensing basis event that you traditionally consider for light water reactors don't really make sense for this technology. So the task is to identify events.

So we're going through the issues again based as represented in the July 6th letter. Our feedback on licensing basis, they want us to -- We think that the frequency consequence curve and the identification of top level regulatory criteria is reasonable. That said future Commission policy may consider alternate TLRC and F-C curves.

We think the proposed plant year method is reasonable for using this for plants with multiple reactors modules.

CHAIR ARMIJO: Why is that?

DR. CARLSON: I think I'll go to this slide. This is a slide the DOE produced for us during the last year in our interactions that has their blue frequency consequence overlaid with the NUREG 1860 frequency consequence curve. What they did though was they plotted the NUREG 1860 consequence curve as though event sequences were considered on per plant year as shown on the vertical axis there as opposed to per reactive year in NUREG 1860.

And so the criteria in NUREG 1860 works best per reactor year meaning that if you change the number, if you increase the number, of reactor modules at a plant, the acceptance criteria for those offsite change.

And I would posit that the public really doesn't care how many reactors you have at the site. They care what's coming at them from the site. So we think that's reasonable. We also think that it's of course a very reasonable way of addressing events that can cause releases from multiple modules.

CHAIR ARMIJO: You're talking simultaneous release.

DR. CARLSON: Yes.

The selection approach for LBEs is generally reasonable, but over the risk based in some respects as we've been discussing in search of better language Option 2 was resulting a set of LBEs from their process may have to be supplemented. So we think that it may be necessary to supplement their DBE-derived DBAs again where DBAs are derived from DBEs by assuming only safety related equipment responses. So you may have to supplement those with deterministically postulated DBAs and/or DBAs derived from events that they would say are in the BDBE region.

CHAIR ARMIJO: Don, what do you mean by overly risk based? You don't believe that there risk numbers are reliable enough?

DR. CARLSON: It's hard to say how reliable their risk numbers are until we actually see a PRA. But I do believe that because there's a lack of experience with this. There's limited experience with the technology and no experience, no modular HTGR that have been designed or operated.

CHAIR ARMIJO: Well, maybe not, but ABR did pretty well.

DR. CARLSON: But that was not a modular HTGR. I'm very familiar with ABR. I've worked there for five years.

CHAIR ARMIJO: I've been there.

DR. CARLSON: Yes.

CHAIR ARMIJO: Great little reactor.

DR. CARLSON: Yes, but it was not a modular HTGR. They did some proof principle type tests there.

CHAIR ARMIJO: Yes.

DR. CARLSON: Those were very interesting.

MEMBER CORRADINI: Can I because I think I know the answer? But I just want to make sure I've got it from what you were saying. So the third bullet and the reason you need to separate from the postulated DBAs and the DBAs right from BDBEs is that the design is not -- One of these three or all of these three, the design is not complete. There's an uncertainty in whatever the risk numbers they're doing or there is incompleteness.

DR. CARLSON: It is all of them, but I would take some latitude.

MEMBER CORRADINI: In completeness and uncertainty.

DR. CARLSON: Uncertainty in the PRA numbers. I mean it's hard to assess the reliability of the uncertainty estimates being looked at.

MEMBER REMPE: So if someone came in with the perfect PRA which would be evaluated at a higher screen and believable data to support that PRA you might not revoke from the traditional requirements.

DR. CARLSON: I don't know. Mark, do you want to say anything more about the PRA and what we think about relying on it under an Option 3 approach as opposed to what we would do as an Option 2?

MR. RUSSO: Yes. We --

CHAIR ARMIJO: You are?

MR. RUSSO: I'm Mark Russo from NRO staff from the Severe Accident PRA branch. Yes, I think there's definitely cause to be concerned given the level of information that we've got, what the degree of uncertainty is going to be and talking these points down on the frequency consequence curve.

As Dr. Stetkar has already commented, it's not even clear what constitutes a point. Is it one sequence or a bucket of sequences or whatever?

But given the issues with data, new systems, there is certainly -- We would certainly expect a fair amount of uncertainty, a great deal of uncertainty.

MEMBER CORRADINI: Can I ask you, Mark? Since the last slide, Slide 15, quotes the staff 25 years ago.

MR. RUSSO: The ACRS has this role as far as I can tell.

MEMBER CORRADINI: So did something change in the uncertainty range that at the time they judged bounding events? Has something changed? Or is it just that the design then is not the design now?

I'm still struggling with the source. Is it design? Is it the PRA given the design? What are the barriers to better uncertainty? Well, I looked this up and indeed this was said. I looked at the ACRS record.

MR. RUSSO: From my perspective I would say, I mean the design -- Modeling the sequence without the numbers and stuff I think is great forward. You're going to know what the systems are and I'm sure they deal with gas. I don't think there's anything there that that's much different.

You know, I think the biggest areas are data, failure data, because of systems we don't have experience with, don't have service. Now I'm not sure if you're aware of it but we didn't get a PRA. But we got a White Paper right after the other White Papers. It was called the PRA White Paper.

And it's referred to in the other White Papers a lot. And we refer to it in our assessment, although we read it. But we didn't review it like we did the other ones. And mostly it's a plan that describes how they're going to do the PRA.

And they do identify the different types of data they're going to need for this model. And they do make a qualitative assessment about which ones have more uncertainty than others. Whether they're going to be able to use water reactor data because the components are the same. They're pumps and whatever.

That would have a lower amount of uncertainty. Some of the areas where there's new systems and gas systems which we don't have as much experience with they'll try and use as much as they can from the gas coolant reactors in England. But they recognize the consumption.

So I think just like the ESBWR and all of the new designs, the IPWRs, we've always been concerned about the data or about these squib valve data, what we can learn about the squib valves, brand new design. So I think that's one of the main areas.

I think the other one would be that when you look at these points that are plopped on this curve a big part of this is the transport of radionuclides. It's the mechanistic source term that's buried in those points. And to me that's probably going to be the most complicated part of doing this PRA is that part of the sequence.

MEMBER CORRADINI: Okay.

MR. RUSSO: And so there will be uncertainty in that, too. We haven't done that before. I mean the technology is there I mean I think. Sure, there will be uncertainty.

But I also think all the stuff is really saying here is that they want to make sure that there's allowance for addressing defense in depth because of uncertainty in this design. And I don't think there's an intent to do anything different than what's been done 30 years ago where you came in with a design.

The designer said, "I've gone through and done my FMEA. I've identified the events and I have some assessment of the frequencies." And at some point you're going to create the envelope. And at some point you're going to argue about should this one be dropped off. Should vessel failure be dropped off or not?

I commend this approach and it's bringing in the use of reliability assessment, the PRA, to help get a better handle on what these frequencies of different events are. That would be helpful with coming up with the envelope.

But given that there will be uncertainty I think you're going to end up the same way with starting with an envelope that includes all the PRA design basis events which is fantastic. But you're still going to be at this point where you're going to struggle with do I need some that I just want to test this design against. And there may be some conservative binding kinds of events.

But those I agree with the designers. You first identify those through the actual design and technical allowances. You look at what do I know. What is all the experimentation and analysis done tell me about what I expect the frequency to be?

So it's got to be a rigorous technical analysis. I don't think that the staff is saying that they're just going to dream up something out of the blue and say, "We don't care what the frequency is."

MEMBER CORRADINI: I'm going to stop you.

MR. RUSSO: Yes. Thank you.

MEMBER CORRADINI: That's alright. The last part that you said I'm curious if Don is in charge of this show.

MR. RUSSO: Yes.

MEMBER CORRADINI: Is the recycle of if you come up with something that is deterministic that doesn't fit into their mapping either because it's way low or it isn't there going to inform and after recycle there would have to be an analysis as John suggested? I mean if I were on the designer's side of this, I would say, "Wait a minute. This is not here or it's way down there." And it's way down there because of analysis that will show you versus thou shalt take this one. End of story.

That's what I think. To recycle back into the analysis I think is very important. Otherwise you're going to come up with things that could be a bit out of bounds.

MR. RUSSO: Yes, I think it has to be that way. I don't think you can just ram something down somebody's throat. They give you come west and this is what we think. And if we say "Well, we know there's one down there. So while you really think it's down there."

"No, I disagree. Show me more." We do this all the time.

MEMBER CORRADINI: Okay.

MR. RUSSO: And sometimes it's very, very difficult because there's a lack of information and it's going to end up being judgment and consensus and all that. Thank you.

MEMBER SKILLMAN: Don, I want to go back to that second bullet. I'm not comfortable with the little -- Yes, with that sketch that you show. I mean this technology is new. There isn't a lot of operating experience for this type of machine. And because that is the case it would seem to me that at least until there's some run time to really understand how a modular concept is successful, then the risk really ought to be based on per reactor year.

Another variation is you don't know that these four or six or ten in a plot are going to be operated the same way. And so they can each have their own operating history, their own personality, their own DDT generation rate. So it seems like this is a clever way to clump risk when in reality until there's some experience it may be more prudent to govern by reactor year versus plant year.

DR. CARLSON: I think this discussion is really appropriate when you're looking at licensing multi-modular plants. But the task before us is to really license the prototype which is one module. So I think when you focus on licensing a single module there's discussion that comes into mind.

MEMBER SKILLMAN: I agree with that. But when you say we're going to have four or six in an array I think there's another discussion that needs to occur.

DR. CARLSON: Yes, and there was a discussion of site risk in past SECY papers. I think SECY 05. I can't remember the number. The ACRS wrote a letter on that. And the issue that was difficult at that time remains difficult. But if you have a new module reactor plant site and have an existing reactor site, how do you portion this between those two?

We didn't go there in our discussions with NGNP. We were busy looking at this from a module plant that's at a green field site.

MEMBER SKILLMAN: For a single modular plant.

DR. CARLSON: Yes, for a single modular plant.

MEMBER SKILLMAN: Then I think the argument is back on the table.

DR. CARLSON: But for licensing the prototype it's kind of a moot point because it's a single module.

MEMBER REMPE: Except that the site could accommodate one module because that's why I think they performed it that way at this time.

MEMBER SCHULTZ: That's fine. But are we arguing about something that will be the licensing approach for ten modules? Or we still don't have a prototype?

MEMBER CORRADINI: I think there may be some confusion. The way they do it here per plant year.

MEMBER SCHULTZ: I might be wrong about this.

MEMBER CORRADINI: Because they're doing per plant year, they're actually taking the population of all modules. It's actually more conservative than doing it on a per reactor year basis.

VICE CHAIR STETKAR: Ten modules together must meet the criteria.

MEMBER CORRADINI: Right. Ten modules together. The assumption here is that I would have ten failures simultaneously. So it's much more conservative.

MEMBER REMPE: And they do have to come in knowing that was something that we used to discuss and kind of have an idea of how many you're going to put on the site when you start off on the sites.

CHAIR ARMIJO: Everybody is in agreement.

DR. CARLSON: I thought I knew this F-C crew, but I'd just like to note that there are many different F-C curves that we could come up with. We came up with one in some of our REIs. The ACRS wrote a letter in 2007 on the NUREG 1860. And their comment on this red F-C curve was that the 5 millirem criterion from Appendix I ALERA was only restrictive with essentially only things that really restrict important. So we see the NGNP curve being more consistent with the ACRS comment on that front.

Yes, we think the frequency cutoffs are reasonable for the last bullet for HTGRs. We're not sure they would be reasonable for other technologies. But we think it's reasonable for HTGRs that provided the PRA's full scope. And I think we understand what we mean by full scope. And that's exactly what DOE had proposed.

Furthermore, the processes for assessing are generally reasonable for the LBEs, the meaning of that sequence frequency. We look at uncertainties and event sequence frequencies and consider the consequences in relationship to the criteria. They overlap the frequency ranges for each category.

The calculation methodology uses consequences from full sequences, best-estimate mechanistic source term which is the next topic with realistic or conservative treatment of uncertainties.

The proposed use of realistic source terms for compliance in the case of anticipated events and beyond design basis events needs further consideration. The staff has issued SECY 05-0006 was that the plants should be conservative for all categories. However, DOE provided some rationale for considering their proposal and for the consideration probably within from the Commission.

Also they have a process for categorization of treatment of safety related equipment. We think that their approaches are reasonable and commensurate with ensuring that they perform their safety functions in the LBEs.

The next big issue area was Mechanistic Source Terms. First, the staff and the Commission and the ACRS has been receptive to the concept of mechanistic source terms for advanced reactors for many years going back to the early 90s for MHTGR. And that was reiterated for PBMR ten years ago.

So the definition of mechanistic source terms you could think of it as being in light water reactor space something like the full-blown MELCOR analysis. Their definition of source term is like the PRA Level 3 source term. That's their definition of the source terms and they are very event specific. And they're mechanistic to the extent that can be justified.

They also take account for the features of the reactor design, etc. All the barriers. This is very consistent with the past positions both of the staff and the ACRS and the Commission.

The DOE/INL has identified key fission product transport phenomena for NGNP and they have reasonable plans for evaluating and characterizing in their NGNP fuel program which I'll discuss a little bit more later.

We believe that the AGR program activities are important in this area. And they should be include additional planned activities that we identified through our assessment interactions to better address the effects of moisture ingress, air ingress and effective dust on radionuclide transport.

MEMBER RAY: Before you go on, I apologize for -- I'm doing the best I can to keep up. But it's not easy. I'm trying to compare what was presented in the subcommittee with what you're presenting now. And for example in the license basis event selection of the presentation on April 9th, there were seven issues broken down for discussion if you recall.

DR. CARLSON: I didn't have time to go through it at that level.

MEMBER RAY: In four of those cases in

four of those issues which it wasn't much longer than what you said, but in any event the words "future Commission direction may be appropriate for this topic appearing in four of those seven cases." I was trying to hear while I was looking at this. Is that still true? Is that what you said the same thing you just said that you didn't have time to say it?

DR. CARLSON: I would say it's still true. I think we need to be careful about what we really go to the Commission with. But we say potential needs for Commission direction on some of these issues.

MEMBER RAY: All right. But I'm just trying to make the committee aware that what the subcommittee heard was repetition over and over again of future Commission direction may be appropriate for this topic. And I just wanted to have you say, yes, that is still true.

DR. CARLSON: Yes, that is still true.

MEMBER RAY: Okay. Because if I just look at what you're saying here I don't get that message at all.

DR. CARLSON: I didn't put those statements in here, but I will try to wrap up with some statements on where we think the Commission direction might be.

MEMBER RAY: Okay. Thank you.

DR. CARLSON: So I think most of us have seen this diagram. It's been around for probably 40 years. It's image courtesy of DOE. The DOE data from Bob Hanson. And I think it's been around for about 40 years. But it does show all of the barriers that we're considering, the fuel kernel, the coatings on the particles, about six billion coated particles in the reactor core.

And then the transport of the radionuclides through the coatings to the fuel compact matrix into the graphite block into the circulating helium pressure boundary into the circulating helium and then deposition at various places in helium pressure boundary in the form of plate out and dust and then in accidents you get various mechanisms for mobilizing and releasing those fission products that are deposited around the system.

An interesting aspect of the source terms are very low because you don't have major core damage. You don't have fuel damage. And the source terms are low. So the accumulation of long term fission products like cesium-137 and strontium is significant. So releases after 40 years of operation are being substantially higher than after four years of operation. This shows all of the boundaries including the reactor building.

MEMBER CORRADINI: I guess what you just said I'm processing. Can you repeat about why things are going to build up here that they wouldn't in light water reactor? I missed that. I'm sorry.

DR. CARLSON: I think they build up in light water reactor.

MEMBER CORRADINI: All right. But I thought somehow you were making a contrast.

DR. CARLSON: They are significant. I think they're kind of in the noise of the source term of the light water reactor compared to what you're getting from fuel damage in the light water reactor.

MEMBER REMPE: So this is basically a licensing condition if we were an LWR coming forward in some of the design certifications we've seen. You would do it for a period of time probably.

DR. CARLSON: The prototype testing?

MEMBER REMPE: Yes. And when you say prototype, that could be the first plant that's full scale.

DR. CARLSON: It wouldn't be identical to the standard, but it could look a lot like it. But it would need additional features to allow instrumentation removal and instrumentation and things like that.

MEMBER REMPE: For temporary effect.

DR. CARLSON: Yes.

MEMBER CORRADINI: Let's just make sure that I'm clear about this because one I want to be clear about. So it would not necessarily be normal operation. You would have to take it through some paces to show that what you thought was happening with definable transients actually do occur here. So you would have to take it through some unusual paces.

You would probably have to go through power ascension. You would probably have to extra instrumentation. So if I were an owner operator wanting to get revenue out of this, I'm not going to get revenue out of this for a while because -- not that we care of this here -- I wouldn't get revenue out of this because I would have to take it through its paces.

DR. CARLSON: I think that's a correct statement.

MEMBER CORRADINI: Okay.

MEMBER REMPE: But for how long? I guess I'm still puzzled about this. This is something that's been discussed a lot. And what is it you're envisioning?

MEMBER CORRADINI: Well, we're arguing with each other out loud.

MEMBER REMPE: Yes.

DR. CARLSON: Speaking from the staff's side, there was a lot of discussion on our part of wouldn't be nice if we had a little bit more design information and could engage in a strategic discussion of how you would do this prototype so that you get the information you need in a few years as opposed to two decades.

MEMBER REMPE: So you're thinking of making them do testing for a couple of years.

DR. CARLSON: Oh, I think so. Yes.

MEMBER REMPE: And you're thinking of transients, not just normal operation. Could they get power out of it for a couple of years?

DR. CARLSON: I listed some things of likely impossible. I would consider the first three that I listed here as likely, almost common sense.

MEMBER REMPE: Yes. And that could be done while they're producing power and making money.

DR. CARLSON: The fourth one would be where you're trying to simulate some accidents. You could possibly do that. That would be more challenging. Yes, you could shave off some significant uncertainties perhaps if you did that right.

MEMBER CORRADINI: So let me just take this a little step further. Is if fair to say that -- now if it's not fair you stop me -- any nonlarge light water reactor, even a small modular light water reactor, may have to go through certain of these paces to create the necessary certainty for staff to unwrap, unbundle, relax what you might have to put on this as restrictions for the first one? Is that a fair statement?

DR. CARLSON: Yes.

MR. MAYFIELD: Let's be a little cautious with that one.

MEMBER CORRADINI: That's why I said you could stop me.

MR. MAYFIELD: Where we have well-understood technology, then we would look at pre-operational testing just like we do with the large lights. If you've got some aspect of it that you needed to invoke the prototype licensing provision, then we would expect testing to validate whatever that shortcoming is that's being addressed through the prototype provision.

The notion with high temperature gas and it's speculation at this stage because we don't have a specific application to address is you might have to go through more testing for a longer period of time than if you had a more proven technology. But until you have a specific design and specific issues you're trying to address through the prototype provisions, it really gets dangerous to speculate is it days, weeks, months, years, decades. I really don't want us to go there absent more specifics that would need to be addressed through the prototype provision.

MEMBER REMPE: Okay. So then I guess if I were somebody trying to do this, I would say "Well, how much money, how big does it have to be? Can I do something that's half scale and do this and give you an update if it's cheaper?"

DR. CARLSON: Actually, the regulation says 10 CFR 50.43(e). It's got to be full scale prototype. So, of course, you can always try to get an exemption or exception and do something to scale. But I would think full scale is essential here.

MR. MAYFIELD: A prototype provision or regulation is contemplating the full scale reactor. You can address some of the things you might need to or might want to address through a prototype. But you can address that through other testing. We're not saying you have to do all the testing with the prototype. But there very well may be the expectations.

(Simultaneously speaking.)

MEMBER REMPE: -- the regulation. And it wasn't clear that you had to have a prototype for everything.

DR. CARLSON: The expectation is you're going to have a full scale prototype -- prove out pieces that you can't reasonably prove out. Don't have data or can't do that. Separate phases or that's the notion.

CHAIR ARMIJO: Mike. Likely impossible of this set of testing requirements which you would say right now would be required.

DR. CARLSON: I'm saying the first three are --

CHAIR ARMIJO: Okay. And the rest you might address them or you might not. But the top three are required.

MEMBER SCHULTZ: And five would more likely be done with a separate effects approach rather than the prototype.

DR. CARLSON: Yes.

CHAIR ARMIJO: Five we do with fuel stuff all the time.

DR. CARLSON: A whole gamut of separate effects. The point is that you do enough separate effects so that the designer is confident that the testing of the prototype isn't going to have a lot of bad surprises.

CHAIR ARMIJO: Okay.

MEMBER RAY: This is mere semantics probably. But do you differentiate between prototype and demonstration plan. A full-scale prototype many people call a demonstration plan.

DR. CARLSON: You could license a demonstration plan without the prototype technical provisions. What we're saying in the licensing strategy report to Congress specifically said prototype technical provisions.

MEMBER RAY: Do you understand that because I'm still -- it's vague.

CHAIR ARMIJO: I don't think we have time for semantics.

MEMBER RAY: Evidently you're trying to communicate something with the word prototype and I'm just trying to understand what it is as opposed to --

DR. CARLSON: I could put up the

regulation.

MEMBER RAY: No, no. You're just using the word out of the regulation is what you're telling me.

DR. CARLSON: Yes.

MEMBER RAY: And if somebody were to call that a demonstration plan, would that be in conflict with the regulation?

DR. CARLSON: No. You can call it what you want.

MEMBER RAY: Okay. It's important.

MR. MAYFIELD: That's an important distinction. This is Mark Mayfield again. If you seek to invoke the prototype regulation 50.43(e), that's going to bring about some very specific things that the staff will look for to be addressed through the testing and operation of that prototype plan so that the license conditions that would be invoked in granting that license can be removed.

MEMBER RAY: All right.

MR. MAYFIELD: Okay. So the demonstration notion is a nice philosophical concept. It's not embedded in regulation. Prototype is a very specific piece of the regulation that contemplates you may not have adequate data to satisfy all of the regulatory criteria in advance. So you can do that three testings where those license conditions, other constraints, only operations to ensure public health and safety while you were validating the things that you didn't have adequate data to support.

MEMBER RAY: But in my experience a prototype plant might also not satisfy all the license conditions that would be applicable to a demonstration plant or the first of a series of commercial plants.

MR. MAYFIELD: A demonstration plant is going to satisfy all the regulations. It's going to satisfy all the regulations and you're going to operate it to prove that life is good. The prototype is going to have some specific conditions imposed on it at licensing that a demonstration plant might not.

MEMBER RAY: Okay. Got it.

DR. CARLSON: Okay. Moving on as we noted with the subcommittee previously we think that peer review of the PRA is very important in that particularly mechanistic source terms or the PRA component is going to be subject to peer review and staff review.

The further consideration of bonding events with air ingress and moisture, I'll get more into that in a couple of slides. And as I said before source terms for compliance, can you consider compliance based on realistic as opposed to conservative? That's an issue for further consideration.

Okay. So functional containment. It's intimately related to the source terms.

MEMBER RAY: Could I? One last thing. I just was again looking at the subcommittee presentation and I think I want to underscore this. A graded EP may be different for NGNP prototype plant versus subsequent standard plants. I mean that's what I was trying to make clear.

MR. MAYFIELD: There are a lot of things about a prototype that might be different. You would prove out through the prototype testing so that you would relax those constraints on Unit 2.

MEMBER RAY: Sure.

MEMBER CORRADINI: Okay. So you were going down a path I wanted to make that I'm not misinterpreting which is that the prototype gives one the advantage as I understand your description that you would start I'll use the word earlier but start in some manner that you're more restricted. But as you prove it out or move uncertainty, that whatever a demonstration plant is would have more I'll call it long-term and I'll use the word reasonable restrictions for safety regulation.

MR. MAYFIELD: Yes. Let me try this a little differently.

MEMBER CORRADINI: You'll do a better job than I.

MR. MAYFIELD: The notion of licensing a prototype there would be some aspects of the design of the supporting data that are not as robust as the applicant or the staff might like to see to just grant a license. We would impose in principal. The concept is we would impose like through license conditions, perhaps power limits, perhaps different ascension testing, different trip setpoints, to assure the safe operation of that design while you are operating it, both normal operation and some of the simulated transient to gather data to demonstrate the safety operation of that plant.

As you gather adequate data, the licensee will come back, seek to have that particular license condition removed so that at the end of the day they would have all of those license conditions removed. And now you would have operation that's consistent with the regulatory structure where we now have adequate operation and testing data to support.

MEMBER CORRADINI: Thank you.

CHAIR ARMIJO: So it's evolved into a demonstration plan at that point.

MR. MAYFIELD: Yes.

MEMBER CORRADINI: Thank you. Does that help?

MR. MAYFIELD: Yes, that' helps a lot.

DR. CARLSON: That was a finite testing period. So the definition of functional containment is very consistent with what we considered 20 years ago. And in SECY-03-0047 and you could read the definition. It's reasonable. We are supposed to come back to the Commission some day with functional containment form of standards. DOE discussed those with us. What they're proposing is essentially identical to what the staff proposed in SECY-05-0006 with the important addition at the end specific to modular HTGRs with limiting air ingress after helium depressurization accidents. And I'll get into that a little bit more in a couple of slides.

They also wanted feedback on the AGR fuel program activities. And we find that the scope of their AGR program activities is generally reasonable and complete in the context of prototype testing. That doesn't mean if you do it you don't have to be testing the prototype of course.

Early AGR irradiation and safety testing results seem to be quite favorable. So this is a major accomplishment on the part of DOE and they may even be establishing new standards for TRISO fuel.

Now completion of the plant AGR activities is key for modular AGR safety case. The AGR fuel program should continue to give attention to such areas as we say in one of our assessment reports" specification of fuel service conditions for normal operations and activities based on specific design information; evaluation and treatment of AGR fuel test irradiation temperature uncertainties. We saw an interesting report about that this last year. They seemed to be doing a good evaluation of that, but the uncertainties are significant. And potential needs for additional fuel and fission product transport data for bounding events, I'll get into that a little bit more.

As we've said, the prototype testing is a little more detail for the transport fuel irradiated in the prototype we would want to do testing on that to fully address the coating interactions with plutonium fission products. HGHP produces in fission more plutonium than what you get in water cooled test reactors like the ATR.

MEMBER CORRADINI: I remember this from the SECY. But if my reactor physics is wrong you'll correct me. But the time scale for what you just said is years. It's not months.

DR. CARLSON: We're talking about the irradiations.

MEMBER CORRADINI: Yes. Okay.

DR. CARLSON: The irradiation tests and such.

MEMBER CORRADINI: So licensed fine. I got it.

DR. CARLSON: So the ATR and AGR are irradiation systems. And the ATR don't give you the fission product in the choice which is a total indication that it would be prototypic and those fission products can affect the TRISO fuel product coatings. And that came out in the TRISO PIRT.

The temperature effects of these kinds of fission product interactions, the coatings aren't fully addressed by accelerated irradiation. So real time irradiations are important. And the irradiations in the ATR are really emphasizing the high ends of irradiation parameters. High temperature, high burn-up, high fluence.

We think that more prototypic combinations of irradiation parameters may or may not give you difficult performance. It remains to be seen. And then again testing and surveillance to confirm core operating conditions, hot spots, etc.

CHAIR ARMIJO: Then to address this issue of the plutonium fission products, what do you have do? Do you have to test?

DR. CARLSON: Well, you have to irradiate it in an HTGR and preferably the prototype. So the conditions are fully prototypical.

CHAIR ARMIJO: So that would be fuel that's removed after a certain amount of irradiation and you verify in hot cells or some other way.

DR. CARLSON: Through safety, in-depth testing you do PRA like we're doing in the AGR program on the test agreement.

MEMBER CORRADINI: But you would need time. You would have to cook it longer before you look at it.

DR. CARLSON: Yes, it would have to go in your discharge unit.

MEMBER CORRADINI: Okay.

CHAIR ARMIJO: But you don't have to have irradiations in another HTGR somewhere else in the world and then use that as a prerequisite before you would license this.

DR. CARLSON: I think that if you did it might reduce ever so slightly the scope the of testing the prototype. But we can talk about that.

CHAIR ARMIJO: Okay. I just --

DR. CARLSON: What is interesting that the German program they did test irradiations in the ABR and the Chinese and the Japanese have done test irradiations in the HTGRs.

So the staff agrees that the core melt accident for event selection for plant siting and functional containment assessments. We believe that the core melt accident that is at issue of light water reactor for the footnote in the regulations may not be applicable to modular HTGRs. And this is consistent with what the staff said 25 years ago for the MHTGR.

MEMBER RAY: I've taken a note every time somebody referred to 30 years ago, 25 years ago, 20 years ago. Quite a few times. And I guess I'm just beginning to wonder. Maybe that's part of what's going on here. We're looking at the way things used to be done and we're in a different era now. I just offer that.

I know that we repeat it over and over

again. This is the way we did things in the past. And I'm not sure that that is in fact what we're facing today as a society. But go on. You said it again. So I just wanted to make my point.

DR. CARLSON: I think in reviewing what the staff did years ago I think they did a really great job.

MEMBER RAY: Without doubt. That's not what I'm talking about. I'm talking about what you've not yet talked about and that is Commission decisions and policy that may be still from 30 years ago. But the problems that we face today may be in need of something different. You'll come to that.

DR. CARLSON: This is where I address Dr. Corradini's question of what has changed. You were reading what the ACRS and the staff were 25 years ago.

MEMBER RAY: You're right.

DR. CARLSON: Yes. What chimney effect interferes there? We took this to the Commission and the Commission came back to us with an SRM that said and I'm prepared to read it here that "The Commission believes that for the MHTGR the staff should also address the following type of event sequence." And this was after they looked at all the bounding event sequence that the staff proposed on the MHTGR and we saw some of those plotted today in the slides presented by DOE INL. And said, "We want you to also consider the following types of events, the loss of primary pressure boundary integrity whereby air ingress did occur from the chimney effect resulting in graphite fire and the subsequent loss of integrity of the fuel particle coatings."

So the Commission said, "You looked at some bounding events. But we want you to look at more and we want you to focus on air oxidation of graphite."

Now there is one thing I would change about NUREG-1338 and I said so last month. And that is there's a section of NUREG-1338 from 1989 that is called graphite fires. And they said that Chernobyl was a graphite fire of a significant type and Windscale was a graphite fire.

Now we have, and I think this has been presented to ACRS in recent years, presentations by our graphite expert in the Office of Research. I think Dave Petty also presented something in recent years. They looked at Windscale a few years ago. I think it was in 2006. They had photos. Graphite is there for the most part. So what burned at Windscale was the metal fuel. And it took some graphite with it. Likewise with Chernobyl. Most of the graphite is still there.

So, yes, I think what we wrote about graphite fire in NUREG-1338 we would change that today. It in fact is hard to make graphite burn. Some people compare graphite to coal and that's not a good comparison at all.

MEMBER CORRADINI: Don, you're a perfect straight man. Wouldn't -- If I had any of the Commissioners from 20 years ago say, "You guys were just technically wrong. You shouldn't have said this because there was no technical? Or is there a possibility this is just a frequency variable?"

DR. CARLSON: I think what the Commission wrote down in the SRM is basically reasonable.

MEMBER CORRADINI: So there is a possibility of having a high point vent where I would just cook the core.

DR. CARLSON: I'll go into that a little bit now.

MEMBER CORRADINI: Okay.

DR. CARLSON: And I did last month if you recall. The SRM is fundamentally sound I think. It does reflect a desire to understanding the safety terrain.

Okay. What are the bounding events? I think it's important for the staff and it's our job to understand the safety terrain to answer the question "What would it take to get a big release from these reactors?" And then to say, "Okay. What is it that keeps us from getting there?" Those are what I call safety terrain studies.

And it's really not PRA per se. It's just you take the basic design concept and just assume a bunch of things to see where it takes you. See where the safety terrain is. And then we go back and say this is how we don't get there.

We discussed this and this is not in the White Papers. But the language that we agreed on during our discussions over the past year was the applicant should submit for NRC consideration risk informed selection of siting events, building on the types of bounding events that the staff imposed on them for NUREG-1338.

And then furthermore to address the SRM from SECY-93-092 to be sure there are no cliff edge effects which would be high dose consequences. And understand what the safety capability. We should be further informed by bounding effects that take insights from exploratory studies.

MEMBER CORRADINI: So can I just probe this? So what you're really saying when you say safety terrain out here I hear consequence studies. That is I'm not going to think about the probability of this occurring. I'm going to say first off to get it as physically possible. Once I conclude this physically possible I'm going to string a set of events together and say what's the consequence.

DR. CARLSON: Yes.

MEMBER CORRADINI: But what I want to ask is wouldn't have you have to come back. And point back to Mr. Stetkar, you have to come back and ask it's there. But it's way out there.

DR. CARLSON: Yes.

MEMBER CORRADINI: Therefore it really is not reasonable.

DR. CARLSON: Exactly. We're going to use judgment. We're not going to go to things that are way beyond reason.

MEMBER CORRADINI: Okay.

DR. CARLSON: So exploratory events should be physically possible and they go way down into below frequency range. Exactly some exploratory studies like that have been done. If Dr. Powers were here, I think he remembers a presentation I gave 12 years ago in the other ACRS room as part of a quasi-PIRT study that we did in 2001. And I put up a view graph of a study terrain study what I now call it that Syd Ball did for us Oak Ridge back in the late `80, early `90 for the MHTGR.

And they said, "What would happen if you had a rod withdrawing and you didn't scram and you ran the helium circulators? Just kept running them."

You would defeat the negative feedback from Doppler essentially. You would get local even in the fuel up to the 2000 degree range. Now there are probably arguments that would say "Wow, that's not credible. But it's part of the safety terrain."

There were also studies that have been done that would say "Well, what if you have a large break and you give them pressure boundary and you run the shutdown blower system of the helium circulators?" Basically, you're sucking air in. You're exacerbating the air ingress rapid oxidation of that. It could get you in trouble. Okay.

There have been other safety terrain studies that have been published. And I think it would be nice someday if the staff could do that with independent analysis. And furthermore, the siting events we evaluate and this way we're giving you a basis for assessing the retention requirements of a functional containment system.

Now I'll move on with Emergency Preparedness. The backgrounds is that they did submit a white paper on emergency preparedness on emergency planning zone size determination and scales emergency response. We did not do a full review of the white paper submittal because of priority considerations, particularly Fukushima at the time. It was just not practical to allocate staff resources to that review.

DOE/INL did participate in NRC public meetings on EP framework for small modular reactors on IPWRs. It's stated NGNP goal as we've noted is to justify an EPZ at the 400-meter exclusion area boundary. And that's part of the process of the application. We did see that is important.

A year and a half ago the staff issued SECY-11-0152 and it described a general approach for scaling EPZs. It's also important to note that the regulation allows EPZ size for gas-cooled reactors to be considered on a case-by-case basis. And the 5-mile instead of a 10-mile EPZ.

So the approach in the white paper is at a high level consistent with the SECY paper 11-0152. We would be open to considering future proposals by industry, but we're not going to come up with further policy in this area absent such proposals.

And we'd considered such topics as proposed in the white paper, PRA informed approach that includes accident dose assessment versus distance, determining the point at which the probably of exceeding the PAG is acceptably low.

MEMBER RAY: Would you repeat the point about we're not going to do this absent such proposals? I'm trying to find it.

DR. CARLSON: Yes, it's not on the slide.

MEMBER RAY: I know. I'm trying to read and listen to you at the same time. It's a little tough.

DR. CARLSON: I'm sorry.

MEMBER RAY: That's alright. I did have in mind and I was trying to figure out if this is what you were saying. It was again one of these future Commission policy directed statements. It sounded like that's what you were saying. It was in the early session of the meeting saying that maybe appropriate determines the criteria for HTGR containment.

DR. CARLSON: Once we have the specific proposals, then I think we would probably go to the Commission.

MEMBER RAY: What does the specific proposal mean? It means an application I take it or a pre-application at least.

DR. CARLSON: A pre-application.

MEMBER RAY: But something more than what you have now.

DR. CARLSON: And I think that an important feedback is that it's not the designer that gives us that. It's the site applicant with detailed information about the design, the co-located facility and the process.

MEMBER RAY: That's what I recall from our discussion at the subcommittee meeting. I think this is what I make the chicken or egg metaphor, which came first. It's hard to get an applicant if you don't know the answer to the question. But you can't answer the question until you have an offer is what it sounds like.

DR. CARLSON: Yes.

MEMBER CORRADINI: Sounds like a Catch-22.

MEMBER RAY: He calls it a Catch-22. I call it a chicken and egg. Dennis, if he could speak to it, would call it a conundrum I think.

DR. CARLSON: I thought we had an excellent discussion with that last month.

MEMBER RAY: Yes.

MEMBER CORRADINI: Yes, we did.

MEMBER RAY: But I was trying to find the point if it was still there which amounts to what I just said. And do you have anything to offer in terms of how to resolve that conundrum? In other words, if you say I can't get an applicant without first answering the question. But I can't answer the question without having an applicant. Is there any way to solve that dilemma?

DR. CARLSON: That's pre-application review. It's when you have a serious pre-applicant and you have enough design information, enough site information, enough co-locator user.

MEMBER RAY: So you're saying I need somebody who is prepared to become an applicant at the very least.

DR. CARLSON: Yes.

MR. MAYFIELD: This is Mike Mayfield. I think you're right. You'll need to go beyond the philosophical with this and get to the bit more specificity absent the full application. And there are views on the staff that we need to see an application. Not everyone including some of the senior management subscribes to that.

But we need more than a philosophical discussion. And you have to consider in this, and I think Don mentioned this, you need to look at from the emergency preparedness sampling the potential impact of the nuclear plant on the surrounding facilities and personnel. You also need to look at the impact of those co-located facilities on the safety.

And that's why you need the next level of specificity to what this really means.

MEMBER RAY: And we've spent a lot of time trying to understand what you just said. But again the language before was selection of siting source term events. I understand totally about siting and each site is a specific site. It has its own needs and demands.

On the other hand, the question arises as to whether or not there is any source term event that are site-independent enough to be addressed before you have an applicant or even a pre-applicant.

MR. MAYFIELD: In the 11-0152 paper that Don mentions, there's a discussion about a graded EP approach in concept. That's something that we're still willing to consider. But we need more to it.

One of the notions in there is that if you're at the protective action guidelines at the site boundary given accident dose, then you still have to do the all-hazards analysis like the other industrial facility. But you might not have a specific emergency preparedness based on a nuclear plant.

MEMBER RAY: Yes.

MR. MAYFIELD: That's all speculation until you get more specific.

MEMBER RAY: Yeah. I understand that you can't go beyond a certain point without an applicant. The question is whether or not we're at the point where policy direction which is what was referred to repeatedly before is possible to any degree or whether now I can't get policy direction without an applicant.

MR. MAYFIELD: What we have said to the Commission in papers that have subsequent briefings is that once we have specific proposals from the industry and I emphasize industry as opposed to specific applicant that if we get enough specificity in that proposal then we would consider that and potentially bring it to the Commission for a policy determination.

MEMBER RAY: All right. We're just not there yet is what you're saying.

MR. MAYFIELD: We're not there yet. We haven't seen those specific proposals from the small PWR community, not from the gas community. But we're not trying to be obstructionists in this, but we can't reasonably take specifications to the Commission and ask for a policy determination. We haven't figured out how to wrap that one up.

MEMBER RAY: And I don't want to try and solve that now. I just want to understand where you are.

DR. CARLSON: So the rest of these considerations on co-location, they're more in the EP white papers and some other submittals that we didn't really review in detail from DOE. So we're in agreement, but they need to consider all these things. And that would be the consideration in this area.

With that, that's my last slide. I would like to thank the Committee for their comments and look forward to getting your letter so we can address your comments and finalize these products.

CHAIR ARMIJO: Okay. Do I hear any comments from the members? Dennis, are you still on the line? I hope the bridge line is open.

Dennis is our bonafide chairman of the subcommittee.

MEMBER BLEY: This is Dennis. No comments, but thanks to the staff for this presentation. They were very helpful.

CHAIR ARMIJO: Okay. Thank you.

Any other? Let's see. We have no one else on the bridge line. Is there anyone on the bridge line that would like to make comments?

(No response.)

Anyone in the room?

MEMBER SCHULTZ: Sam, there is one.

CHAIR ARMIJO: Give your name please.

MR. SOUTHWORTH: Good afternoon. Just one comment. Finis Southworth. I'm Chief Technology Officer at AREVA Inc. And I'm also an executive board member of the NGNP Industry Alliance. And I just have one comment and I'll try to be brief since you're a little bit over time already.

The Alliance is an industry advocacy group supported commercialization of high temperature gas coolant reactor technology and its stated intent presently of the Alliance is to develop and employ the AREVA steam cycle HTTR design for both process steam and electricity. It has been planned in the Alliance for some years. And it is documented in a business plan that once the first reactor module of a first-of-a-kind plant is constructed, we would presume that under the NRC license conditions we would plan to utilize a two year inspection, maintenance and testing period to demonstrate the operability and the safety of the commercial scale HTGR reactor.

During this period, the reactor would be sufficiently instrumented to obtain necessary data and to validate plant operational and safety characteristics. Tests would be conducted in a controlled manner with various particle levels to demonstrate operability and confirm expected performance.

The HTGR technology is not new as Don has pointed out. The high temperature gas coolant have been and two are still operating today around the world successfully demonstrating the key characteristics. Granted there are differences among the seven test reactors.

We believe there is sufficient test and experimentation facilities available in the U.S. presently and worldwide to allow licensing with a commercial scale reactor utilizing this technology. The fuel, the reactor passive shutdown would be sufficiently tested separately to provide a high level of confidence to operate the first module with ample safety margins to satisfy the requirements of 10 CFR 50.43(e) under Subpart 1 such that no additional safety features would be necessary under 10 CFR

50.43(e) Subpart 2.

We believe this approach is critical for the timely licensing and commercial viability of the FOAK, a demonstration of plant and its subsequent commercialization of the technology. And that's my comment. Thank you.

CHAIR ARMIJO: Okay. Thank you.

What I'd like to do now is take a recess and reconvene at 3:25 p.m.

(Whereupon, the above-entitled matter went off the record at 3:07 p.m., and resumed at 3:25 p.m.)

CHAIR ARMIJO: Okay. We'll start again with addressing the issue completion of Generic Issue of 189: "Susceptibility of Ice Condenser and Mark III Containments to Early Failure from Hydrogen Combustion During a Severe Accident." And Dick Skillman will lead the Committee through the briefing.

MEMBER SKILLMAN: Mr. Chairman, Colleagues, we are bringing this issue in front of the ACRS as an information briefing. And the reason we're doing it is I'm certain that the images are still fresh in your mind of the Fukushima buildings exploding with the hydrogen. And since that image is so raw, the completion of this item is really intended to address hydrogen in containment buildings. I thought it prudent to bring it in front of the whole group.

So what are we talking about here? We're talking about 14 plants of the currently licensed 104. There are 10 PWRs: Sequoyah, McGuire, Catawba, D.C. Cook and Watts Bar 1 & 2, and four Mark III containments. We've talked a lot about Mark Is and Mark IIs. But we really haven't talked a lot about the Mark IIIs. The Mark IIIs are Perry, Clinton, River Bend and Grand Gulf in some 14 plants.

And that this is really about is ensuring that the hydrogen igniters have backup power supplies. And the NRC required those plants to provide that backup power. And the licensees proceeded to provide that power. And we're here today to talk about closure of this item based on those actions.

I would like to recognize Tim McGinty, new Director in NRR. And then introduce Mr. Steve Jones.

Tim.

MR. McGINTY: Thank you, Dick. Mr. Chairman, Committee members. I'm a relatively new director in the Division of Safety Systems in NRR. I really can't add a better preamble than Dick already covered on what we're about to discuss with you in this information briefing.

We did plan a comprehensive briefing because it's been quite some time before we brought this issue before the ACRS. And with that, Steve Jones is on my staff. And I would like to turn it over the presentation to Mr. Jones.

MR. JONES: Thank you, Tim. Good afternoon. Just to mention, I'm Steve Jones from NRR. And I just want to go run through our cases for closing out Generic Issue 189.

To start with an introduction, I intend to discuss the basis for initiating the generic issue, the regulatory requirements that currently exist with respect to combustible gas control, technical information related to the severe accident progression that's of concern for this particular event and early stakeholder interactions we had discussing this issue, the regulatory analysis that was completed, the implementation plans that the licensees developed for this, our verification activities and finally the nexus of this issue to what happened in Japan in 2011. This issue really originated with efforts to risk inform various safety regulations in Part 50 and this relates specifically to 10 CFR 50.44, Combustible Gas Control for Nuclear Power Plants.

In that risk informed effort, three major changes were identified to 50.44, (1) to specify a severe accident combustible gas source term particularly for the new reactors; (2) remove requirements to deal with hydrogen generation during a design basis LOCA as that was considered a very low risk threat to containment integrity; and (3) then modify the combustible gas requirements for the ice condensers in Mark IIIs because of an identified issue regarding the -- Well, really it's the detonation of hydrogen within these two reactor containment types which dominated the failure modes that could affect those two reactors or two containment designs.

In SECY-2000-198, the staff recommended proceeding with the first two issues through rulemaking and the third item through the generic issue program. And the Commission agreed with that approach.

This is really the way 50.44 stands today after those two risk informed issues were implemented. All containments need to have the capability to provide a mixed atmosphere and monitor the concentration of hydrogen in containment. For the large dry and subatmospheric containments which cover 59 current operating licenses, there is no additional requirements based on the large volume and high design pressure of those containment designs. That was based on fragility analysis that determined a low conditional probability of failure.

For the BWR Mark Is and IIs which cover 31 operating licenses, they continue to be required to maintain an inert atmosphere within containment and provide oxygen monitoring capability to ensure that inert condition is maintained throughout an accident.

For the ice condensers in Mark IIIs, the regulation maintained the existing requirements with respect to combustible gas control. That is existing AC powered igniters were considered acceptable. And the existing equipment survivability analysis and containment integrity analysis based on a 75 percent metal-water reaction was considered acceptable.

For the new reactor types which is over on the right at the top, we have a couple new pressure suppression containment designs, the advanced boiling water reactor and the ESBWR. Those are both inerted containment types and they maintain the requirement for oxygen monitors like the Mark Is and IIs. And then also the rule added consideration of significant beyond design basis accidents such as a station blackout.

For the new large dry containment AP-1000, APWR and EPR, they're not inerted. They have to do an equipment survivability and containment integrity analyses but instead of 75 percent based on 100 percent metal-water reaction in containment, have hydrogen control measures that contain less than 10 percent hydrogen within containment following an accident and again add significant beyond design basis accidents into the consideration for that design.

The ice condensers in Mark IIIs have as mentioned an AC powered ignition system. They're really essentially something that would be used in large diesel generator type to provide an ignition source for start-up. It's just a relatively small heat element inside a shielded cover. And they're distributed throughout containment in two trains, each backed by the emergency diesel generators on the site.

The containments have between approximately 50 to 75 of these containments depending on the specific containment distributed throughout. And ice condensers, both the lower compartment and the upper compartment have them. And in the BWR Mark IIIs, both within the dry well and in the wet well outside the dry well area, these igniters are distributed.

In all cases, they are manually initiated by the controlling staff based on emergency operating procedure direction. They're not automatically started or left in operating. The power consumption is typically about a little less than 15 kW per train. So it's not a high power consumption, but far more than the batteries could support for any length of time.

MEMBER SKILLMAN: Steve, would it be fair to characterize as igniter as a glow plug versus a spark plug?

MR. JONES: Yes.

MEMBER SKILLMAN: Thank you.

MR. JONES: Just a hot element. And they're really designed to operate so that they maintain the hydrogen concentration just at about the flammability limit. So if any ignition occurs at that site it would generally just propagate upward. You wouldn't have a three dimensional propagation from that.

MEMBER REMPE: Could you elaborate a little bit more about the emergency procedure direction about when they manually initiate it and what indicators are used?

MR. JONES: Within a design basis accident, there are hydrogen monitors. The direction doesn't really rely on those though. It's based on cooling provisions. If there's recognition and control that core cooling has been lost, that's typically --

MEMBER REMPE: So they put them before you ever have any hydrogen generated.

MR. JONES: Right.

I'll briefly run through the tube containment designs. On the left is ice condenser containment design. There's a separation as I mentioned a lower and upper compartment. That barrier wall covers the steam generator pressurizer and the loop piping and directs any release from the reactor coolant system through doors on the side and up through ice beds. You'll see there's that kind of cross-hatched areas in that diagram. And up into the upper compartment.

What's important to note I think is that even the lower compartment reaches all the way out to the outer edge of the containment and therefore combustion there could overpressurize containment to a point and cause leakage in the lower compartment as well as the upper compartment.

Also this picture depicts what's the configuration as far as the overall design for the

McGuire, Catawba, Sequoyah and Watts Bar plants. They have a freestanding steel containment with a separate concrete shield structure shield building around that. And there is annular space available inside.

The D.C. Cook plant is a little bit more like the diagram on the right as far as the outer containment design in that it's a reinforced concrete with a steel liner and only at the lower portions where the penetrations are is there any secondary structure that can contain any leakage.

The Mark III boiling water reactor diagram is on the right. The important thing to note there with respect to this issue is that the dry well is really almost a square, the square structure in the center, around the reactor. And that does not go out to the outer wall of the containment.

Any release from inside the steam isolation valve would be directed in the dry well, go over the rear wall and into the suppression pool at the bottom here. So the releases would go this way through the suppression and then up into the wet well portion of the containment.

Again, there are two different designs for the outer containment shell. This shows the Grand Gulf and Clinton designs which are reinforced concrete with a steel liner. The Perry and River Bend plants have more like the other picture with the freestanding steel containment and a concrete shield building.

Both these units are intermediate in size in that they're about a quarter of the size of the largest large dry containments. But they're double the size of the Mark I and Mark II containment designs. The design pressure is about a quarter the typical design pressure of a large dry or a BWR Mark I or II for this same power.

Just to go through briefly accident progression, this issue predominantly applies to an extended station blackout scenario because we're looking at it if the diesel generators were available we would presume there would be power available to the igniters to control hydrogen. And that would maintain containment integrity by controlling the combustible gas concentration.

However, in an extended station blackout scenario or other scenarios that have similar effects on a plant like a large fire or possibly a beyond design basis seismic event, you would not have any power to any of the AC components.

MEMBER BANERJEE: How much power does the igniters need?

MR. JONES: On a couple of slides back, it mentioned about 15 kW per train is the design basis loading that used in the FSAR for the diesel.

MEMBER BANERJEE: I mean for the igniters. Do you need 15 kW?

MR. JONES: Yes, per train. That's doing between 25 and 36.

MEMBER BANERJEE: That's a lot of kilowatts.

MR. JONES: Right. It's far more than the battery could reasonably handle. That's why that really wasn't a consideration.

MEMBER BANERJEE: Is that true for all igniters?

MR. JONES: There are passive autocatalytic recombiners that perform a similar function. And those are being used overseas and the EPR has those. And the AP-1000 has a mix of igniters and passive autocatalytic recombiners. And that was considered as part of this issue, but they would take some time to get going before they're operating at peak capacity to recombine the hydrogen with oxygen.

MEMBER BANERJEE: Do they work well in steam?

MR. JONES: Yes. If there is a high

enough steam concentration, I don't -- we're not really worried about combustion or recombination. I think it would --

MEMBER BANERJEE: My concern would be if they get wet. Do they just dry off by themselves or what happens?

MR. JONES: Are you talking about the passive ones?

MEMBER BANERJEE: Yes.

MR. JONES: I really don't have that level of detail to discuss that.

MEMBER BANERJEE: It's fine. I'm sure somebody here knows the answer.

MEMBER POWERS: It's kind of like hydrogen recombiners would start reacting with hydrogen. Technically, a couple of designs and materials out there. Technically, they're just metal sheets with palladium and platinum particles on it or you can have aluminum oxide, things like that.

The problem is no one worries about that passive catalytic hydrogen recombiners is poisoning our occlusion and it can poison with sulfur. It can occlude them by reacting with organic vapors causing carbon undersurface and things like that.

MEMBER BANERJEE: So they're not always.

reliable.

MEMBER POWERS: I wouldn't say that. I think they're very reliable because they don't take any power.

MEMBER BANERJEE: But other than that.

MEMBER POWERS: Will they degrade over the course of an accident? Well, maybe. I mean the problem is really poison. Some plants use them and they check for degradation every few outages.

MEMBER BANERJEE: Okay.

MEMBER POWERS: I mean I think eventually -- They're expensive relative to a glove box.

MEMBER SKILLMAN: My answer to your question is that they will work when they are moist. And the platinum plating recombiners are not too different than what you have in the exhaust of your car. The same kind of recombiner technology and you are actually passing vapor through the automobile engine. And so the platinum or palladium reaction will cause recombination.

So moist is decay. That is what we use in the shipments for the submerged mineralization systems resins from TMI. They work wet.

MR. JONES: Again, I just wanted to discuss briefly the accident progression in the core.

We were talking about an extended station blackout scenario and you really basically have a large steam level forming over the reactor and that would be causing the fuel to begin drying out. As the temperature of the zirconium cladding gets above 1,000 degree you'd get a relatively rapid rise in the cladding oxidation damage. It produces -- It rips oxygen out of the steam molecule and then it puts hydrogen excess heat generated. And that heat can exceed the decay heat of the reactor and also further increases the rate that the vessel dries out.

So you can end up with a relatively fast development of a large amount of hydrogen from the core. This hydrogen could be released to containment through the loop operation in the RCS or deliberate reactor vessel venting. That may have a part earlier in the valve as stuck open or actuated automatically.

Without the operating hydrogen igniters, we expect hydrogen would accumulate inside containment to the combustible level. The conditional containment failure probability for the Mark III and ice condenser types for that scenario is very high, greater than 0.1, our regulatory guideline for defense-in-depth purposes.

However, the Mark III containment because of the design with the dry well inside the wet well is likely to retain suppression pool scrubbing of any releases because it's a little bit harder to fail that interior dry well structure especially for denotations of the current wet well region.

Given that scenario, there is potential for a large early release in the absence of igniter function. However, it's a very low frequency event sequence around I believe it was below 1 E^{-5} for most of these plants or right in that vicinity for reactor year. And there was substantial uncertainty in the consequence determination because of the questions about the end state of the containment and what type of plate out or release would develop in this accident sequence.

During the initial investigation by the Office of Research, they did look at backup power for the igniters and then also looking at backup power for both the igniters and the recirculation fans to ensure the containment environment was well mixed. And lastly providing passive autocatalytic recombiners.

Research's recommendation was to provide backup power to it based on the relatively low cost. And that would be uncertainty in consequences.

MEMBER BANERJEE: This would be backup

power in --

MR. JONES: No, small generators that would be either pre-staged or portable and connected to a motor control center in the electrical distribution system at some point in the auxiliary building where it would be able to get directly to the hydrogen igniters. You need to have the voltage linked with the -- The voltage of the generation would have to match the design voltage of the motor control center.

In order to address this issue, the staff scheduled several public meetings with stakeholders to discuss the technical issues behind this and the accident sequences, the purposed design criteria for any backup power supply and also what procedures specifically to use for implementation, whether it should be emergency operating procedures which are regulated or the severe accident management guidelines which are not regulated and at a lower level of detail.

At that time, there was not any consideration of any other type of procedures. These were really the two main groups.

The interface included several organizations including the Nuclear Energy Institute, the Union of Concerned Scientists, BWR Owners Group as well as the individual owners of the effected units. The discussion areas in these meetings got into the design of the portable backup supply. I mean that is whether it would be portable or pre-staged. A need for detailed design criteria such as how long should that generator function for without replenishment of fuel. How do you enhance its survivability for external events like earthquakes or floods in the area? Also how to deal with the timing for activating a hydrogen igniter. So at what stage in the accident should the backup power be supplied? And that would drive in part whether or not it was portable or pre-staged.

Following these meetings or I guess with consideration of a number of these meetings, the BWR Owners Group suggested the use of the Division III Emergency Diesel Generators powered igniters. Those are the generators dedicated to powering the high pressure course load in the Mark III design.

The staff's concern there is really there's a relatively large fraction of station blackout events that go to core damage where you're not going to have a generator available anyway. I mean if it was available you'd probably have the core spray pump and you would probably not have core damage. That was one issue with that.

But PWR licensees were suggesting this --

MEMBER RAY: Why did they make that recommendation? Did you ever figure that out given what you said?

MR. JONES: I guess in one sense we're just looking at loss of the two power supplies to the hydrogen igniters. And it's true that this third diesel generator doesn't power those. In that sense, some licensees had relatively high estimates of its survivability even with failure of the other two diesel generators. I really don't see it.

MEMBER RAY: Okay.

MR. JONES: And then for the pressurized water ice condenser licensees they had various diesel generators available on site that they would wish to credit for backup power sources. There was also a course discussion on benefits relative to the costs of recommending various options.

So the staff initiated a regulatory analysis in the late 2004-2005 time frame to evaluate the costs and benefits using more plant specific information that was used by the Office of Research. They used the SPAR models for core damage frequency estimates and for estimating reliability of other recovery actions.

This regulatory analysis both considered voluntary measures and rulemaking to require backup power supply. They looked at the passive autocatalytic recombiners, backup power to the igniters, backup power with the recirculation fans, and also repowering the hydrogen analyzers to be able to monitor containment hydrogen concentrations throughout an accident.

And it also assumed different containment failure probabilities for the different pressurized water designs based on a Sandia study that evaluated containment fragilities. Those had conditional failure probabilities from 0.22 to 0.97 of the ice condenser designs.

For the BWR Mark III, they used a standard 0.19 as the conditional containment failure probability of an unscrubbed release. That is for having both a dry well and wet well failure that would allow a direct release from the core through the outer wall containment without passing through the suppression pool.

This regulatory analysis did not fully evaluate external events or security related events.

And to whatever extent that the staff might apply didn't consider directly enhanced defense-in-depth provided by reduction in the conditional containment failure probability.

The results of the regulatory analysis indicated that passive autocatalytic recombiners are substantially more expensive than the backup power supply. And part of that is because of outage duration requirements to install some of the igniters inside containment. I mean recombiners inside containment.

MEMBER CORRADINI: So if it weren't for the installation is the ongoing basis the parts the same cheap?

MR. JONES: I don't have that information. I would say on an ongoing basis --

CHAIR ARMIJO: I would think people wouldn't install something that don't have to be wired up.

MEMBER CORRADINI: That's what I would think.

MEMBER POWERS: I suspect it was cost, the ongoing cost that you have with the parts. For instance, Canadians pull a plate every outage and look at it, go test it. If it fails the test then they replace all the plates. Everything. And so you get into a aging or what caused the plates to fail, vapor, paint, oils, all kinds of things.

So you have to protect them during outage from activities that you would take on. They take a lot of maintenance relative to what was set up and I don't think anybody pays any attention to them after they get installed.

MR. JONES: They did test them periodically. I don't think they're maintenance intensive or anything.

The regulatory analysis also concluded that mixing fans and hydrogen analyzers were unnecessary. The mixing fans were basically because if the igniters are available and operable any combustion will help mix the containment environment. And they are so widely distributed within containment that there is no concern or not a substantial concern with the large.

MEMBER POWERS: In the ice condensers they're all up in the --

MR. JONES: There are some in the lower loop areas as well.

MEMBER POWERS: But they're not in the big regions.

MR. JONES: The ice bed region, no.

MEMBER POWERS: And so do you run into the problem that you can get DDT up through the bed?

MEMBER BANERJEE: What up through the bed?

MEMBER POWERS: Deprivation to detonation transition.

(Simultaneously speaking.)

MR. JONES: I don't have that.

MEMBER POWERS: It seems to me that if people would look at that that it depends on who you talk to. I guess it's just not a clear case of whether you can or can't.

MR. JONES: I do expect that for at least early in the accident a lot of the ice would still be there from them.

MEMBER BANERJEE: Not if you ignite it and there's a detonation run. Is it going to matter --

MEMBER POWERS: Say it again.

MEMBER BANERJEE: Does it have a lot of narrow passages?

MEMBER POWERS: Well, it depends on whether the ice is there. If there is no ice then it's -- I mean there are a lot of baskets that will induce turbulence and that will give you the potential of going to getting deprivation to detonation transition.

MEMBER CORRADINI: You're talking about ice-less baskets.

MEMBER POWERS: Yes. I mean the ice is pretty much gone by the time you get to extensive core damage.

MEMBER CORRADINI: Didn't Marshal -- didn't your buddy test the hell out of this already in their big tunnel? Didn't they put obstructions in? I thought they had with Joe Sheppard.

MEMBER POWERS: Yeah. I mean what they were doing in the FLAME facility was looking at the potential for getting the deprivation to detonation transition.

MEMBER CORRADINI: But I thought there was a database here where they put in the big tunnel obstructions like baskets to see. That's in my memory.

MEMBER POWERS: I don't remember any tests with baskets. I remember lots of tests with obstructions and how much bending you have.

MEMBER CORRADINI: I can send it up to Sheppard to find out.

MEMBER POWERS: I mean all that tells you is you can get DDT. The question is do you get DDT in these kinds of things without -- I mean how much natural circulation do you get? And there is presumably some natural circulation because it's hot down low and cool above or cooler up above.

MEMBER CORRADINI: Right.

MEMBER BANERJEE: Once the deflagration starts it generates turbulence. So you don't have much flow. It's really whether you've got obstructions on how much turbulence you generate behind the obstruction.

MR. JONES: I think really the idea is to get the igniters running early enough that I guess they would capture or begin oxidizing any hydrogen before it enters the bottom of the ice baskets. And then if it's oxygen starved in that region it will go through. And then once it gets to the --

MEMBER BANERJEE: Why don't they put some igniters lower down?

MR. JONES: They are. They are in the loop areas. They're just not in the ice beds themselves.

MEMBER BANERJEE: Somebody must have done a calculation.

MR. JONES: I guess if there was a concern within the ice beds, then I think we'd be dealing with this issue as I guess a compliance issue right now because that would really be a problem with compliance 50-44 itself.

Okay. For the PWRs, specifically the ice condensers, the backup power from these or the backup power provided substantial safety benefits at justifiable cost. Most of that benefit was provided by just the voluntary measures, having a third or in some cases a fifth diesel generator onsite to power the igniters that's independent of what's used to normally power the core or to prevent core damage was providing a substantial benefit. And rulemaking was not just applied after consideration of these voluntary measures.

For BWRs, the Mark III containment design with that inner dry well, the cost of implementing any option were not justified by the increased protection because it's a low frequency initiating event plus a relatively low conditional containment failure probability. And the sensitivity analyses that were performed didn't change those conclusions. And they looked at things like changing the initial containment failure probabilities in particular for the boiling water reactors. Following the completion of the regulatory analysis, the staff continued meeting with effected licensees predominantly about security related issues in closed meetings.

Eventually, staff reached agreement with the licensees about proposed backup capabilities that provided some benefit for security related scenarios. The Catawba and McGuire units credited their establishment of a permanent new power supply direct from their safe shutdown facility diesel generators to at least one of the transit igniters. The Sequoyah and Watts Bar plants were using an onsite portable generator and connecting that with the plant electrical distribution system and power igniters from that.

D.C. Cook had previously installed two relatively large diesel generators that are used predominately for extended allowed outage times for emergency diesel generator maintenance. And these generators are permanently connected into the electrical switch gear and configured such that they could replace any one of the emergency diesel generators at that site. And they installed in addition to that additional operating switches to start the igniters in the event of an accident.

The BWRs all provided portable diesel generators for local power to the igniters. It's providing it as I mentioned earlier to a local motor control center near the containment penetration. And implementation of these backup power supplies was implemented at the level of detail to severe accident guidelines.

MEMBER REMPE: All of these are voluntary actions, right?

MR. JONES: Right.

MEMBER REMPE: And what oversight from the NRC if it's a voluntary action as opposed to something like a further rulemaking or whatever?

MR. JONES: It's a little more difficult. There is a formal commitment process and we do track that and audit it. And I don't get into how we verify that this was implemented correctly.

MEMBER REMPE: And it will be continuing on as the years go by to check and see if maintenance is done on the equipment? People practice to see if their procedures can be implemented in a timely fashion, etc.?

MR. JONES: There is commitment audit process that's ongoing. But it won't necessarily I guess go to this specific item. However, I'll get to other requirements that are coming into play related to this issue.

MEMBER REMPE: Okay. Also the timing. Are all these things going to be done? There's a dead period that we could have hydrogen generation accruing and then is that considered in all these procedures and voluntary actions?

MR. JONES: Part of the verification process was to look at the capability to get the power supply in place within a three hour time period. That should allow sufficient time to identify that you're having trouble feeding the core.

MEMBER REMPE: For hydrogen generation.

MR. JONES: The core for substantial hydrogen generation, yes.

The verification the staff implemented was documented in Temporary Instruction 2515/174. And that began implementation in 2008 and most of the sites had completed that verification process by the middle of 2008.

The major modifications at Catawba and McGuire extended the generic issue process and the last unit was not complete until early 2010. At the same time, Watts Bar Unit 2 was beginning their licensing process. And we requested a commitment. I think there was some problem with their understanding of what exactly we were looking for.

So in late 2010 we received the correct commitment that would implement the same measures at Watts Bar Unit 2 as have been committed for Unit 1. And the inspections revealed no deviations from the commitments.

Next in line, shortly thereafter after receiving that Watts Bar commitment, we had the events in Japan. I considered that accident progression somewhat similar to what we're talking about with Generic Issue 189 in that looking at externally initiated sustained station blackout event and yet core damage with significant hydrogen generation. And of course there was also a significant release due to the containment overpressure, although that was caused by -- At least there is no definitive information about any hydrogen combustion causing that containment failure. It was more likely just in general overpressure and possibly steam explosion.

Nevertheless we considered that in the context, the staff, of developing the mitigating strategies order. That's EA 12-049. And the guidelines for implementation of that order now include strategies to maintain containment integrity. And for the ice condensers in Mark IIIs those strategies include providing a power supply to the hydrogen igniters.

MEMBER SHACK: When I read 12.06, it says even for PWRs you have to have a portable power supply. So does that mean the previous fixes are now going to be supplemented with an additional portable supply?

MR. JONES: That's really going to -- As a commitment the licensees are free to change the previous commitments. Now for Catawba and Watts Bar, I expect that their modifications are going to remain in place. That was a permanent change. For D.C. Cook, they had a permanent change as well.

For the ice condensers -- I'm sorry. For the BWR Mark IIIs, I expect they're going to basically supplant their existing equipment that dealt with this commitment with equipment they're procuring specifically for the mitigating strategies order which typically is a larger portable generator and more of them distributed throughout the site. Also for Sequoyah and Watts Bar they fall in that latter category where I expect they're going to replace their commitment with the flex equipment that they're using to meet this order.

Since that for the mitigating strategies perspective, there's a lot of overlap and I guess interaction between the components. These generators are typically used for multiple purposes, not just for providing power to igniters. They also are used for RCS inventory management for instance to power a charging pump or something of that nature. So they're again relatively larger portable generators.

The benefit here which is what you were alluding to is it's a durable regulatory requirement on this capability. The way the flex order is being implemented provides a little bit better assurance of external events not damaging capability to provide the igniters. Those are the two points from this order.

In conclusion, we feel that effective measures have been implemented to control combustible gas during extended station blackout events. And we've done some verification and inspections to confirm the capabilities that we expect from the commitments.

Going forward, I think the order will enhance this capability. I expect that the maintenance of that flex capability will somehow fit into the inspection program and won't be lost or fall into the background.

So accordingly we're recommending closure of GI 189. We understand the ACRS has already issued a letter to the Executive Director regarding this but supporting staff's closure and we will be proceeding with closing this out this month.

MEMBER POWERS: The events in Japan pertinent to hydrogen combustion could occur in the reactor building which is not protected either by igniters or inerting. Is the agency thinking about responding to that finding since the reactor coolants include lots of equipment needed for design basis accidents?

MR. JONES: I can't really speak directly to that because I'm not working on that issue. But I guess there is a couple of things. One of them is I mean it interfaces with the containment vent order for the Mark Is and IIs as far as if you're able to manage the hydrogen generator in containment and get it fully outside the reactor building.

For the other reactor types, I think that's going to have to be addressed in the I believe it's a Tier 3 item to look at that but that will be over a longer period of time. I just don't work in that area.

MEMBER POWERS: It's just when we think about Mark Is and IIs we think that inerting gets rid of the problem. And if it does unless you get leakage of hydrogen in the reactor. You can be sure the required hydrogen vents in the Mark Is because the vents pass right past the equipment needed for handling the accident.

So now you're banking on not getting any leakage at any time in an accident. And you know you have vulnerable seals and things like that throughout the plant. And it would be unfortunate to have all this protection and then lost it just because of a little hydrogen, wouldn't you?

MR. JONES: I can't address it for the broad spectrum of plants. These plants have a relatively low design pressure to start with.

MEMBER POWERS: Well, design pressure for the Mark I is actually pretty common.

MR. JONES: Right. I was referring to the ice condensers in Mark III.

MEMBER POWERS: Yes, but the ice condensers are really unfortunate designs.

MEMBER SKILLMAN: Other members like to have comments for either Steve or Tim?

(No response.)

Are there any comments from the public?

(No response.)

MEMBER POWERS: I enjoyed the

presentation. Very informative.

MEMBER SCHULTZ: The presentation was a nice documentation of the closure documents.

MEMBER SHACK: I admire the staff's tenacity. I mean they finally got their order.

MEMBER POWERS: Even the main version of 1206 didn't have that in there. But the final one did.

MEMBER SKILLMAN: Colleagues, Mark is indicating there is nobody on the bridge line. Okay. So if there are no further comments, Steve, thank you very much. Tim, thank you. Mr. Chairman, back to you.

CHAIR ARMIJO: Okay. Thanks, Dick. Well, we're finished with the formal parts of the meeting. Now we would like to -- I'd just assume start writing that letter.

MEMBER SHACK: I'd assume not, but I guess we have to.

CHAIR ARMIJO: Why don't we just close. Off the record.

(Whereupon, at 4:17 p.m., the above-entitled matter was concluded.)

U.S. DEPARTMENT OF ENERGY | Nuclear Energy

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
604th MEETING

NGNP Introduction

Tom O'Connor
Advanced Reactor Technologies
Office of Nuclear Energy
U.S. Department of Energy

May 9, 2013

U.S. DEPARTMENT OF ENERGY

Nuclear Energy

NRC-DOE Licensing Strategy – 2008 (Report to Congress)

- **“It will be necessary to resolve the following NRC licensing technical, policy, and programmatic issues and obtain Commission decisions on these matters”**
  - Acceptable basis for event-specific mechanistic source term calculation, including the siting source term
  - Approach for using frequency and consequence to select licensing-basis events
  - Allowable dose consequences for the licensing-basis event categories
  - Requirements and criteria for functional performance of the NGNP containment as a radiological barrier

NRC Staff Positions Requested by DOE

- **NGNP transmitted a letter to NRC on July 6, 2012 reinforcing areas of priority for licensing framework development**
  - Consistent with focus areas summarized in NRC to DOE letter dated February 15, 2012

- **NRC staff positions were requested in four key areas:**
  - Licensing Basis Event Selection
  - Establishing Mechanistic Source Terms
  - Functional Containment Performance Requirements
  - Development of Emergency Planning and Emergency Planning Zone Distances

U.S. DEPARTMENT OF ENERGY

Nuclear Energy

Reducing Regulatory Uncertainty for Modular HTGR Deployment

- **DOE is focused on the resolution of long-standing HTGR licensability issues, and eliminating the significant uncertainty that goes with them**

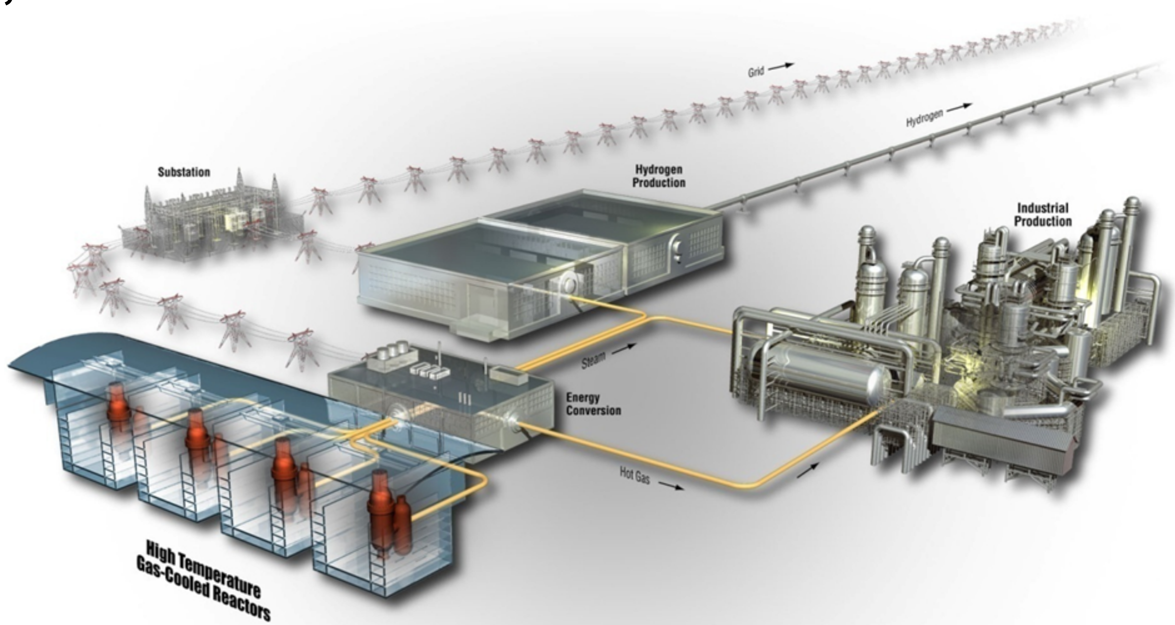
- **Status of key issue resolution generally well understood, with significant progress from DOE-NRC pre-licensing interactions**

- **However, significant uncertainty remains regarding the process for design basis accident (DBA) selection**
  - No apparent lower limit on event sequence frequency
    - Potentially hampers the ability of the designer and applicant to demonstrate that safety margins are increased, as directed by the Commission's Advanced Reactor Policy Statement
    - Creates significant uncertainty for NGNP stakeholders and other advanced reactor designs

NGNP Licensing Overview

ACRS 604th Full Committee Meeting

May 9, 2013



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Next Generation Nuclear Plant

Idaho National Laboratory

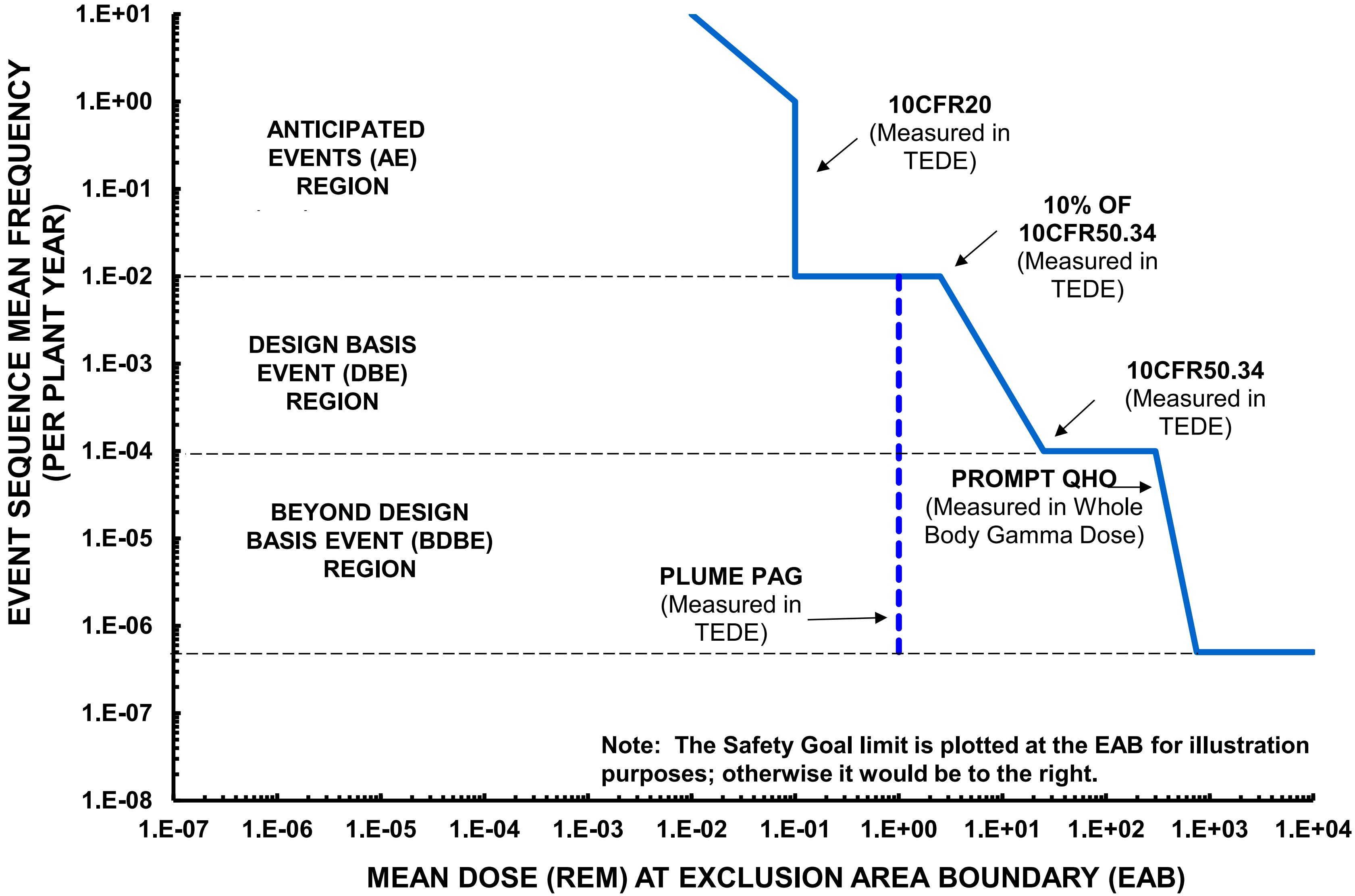
Safety Approach and Design Basis Summary

- Top objective is to meet the NRC offsite dose requirements and EPA Protective Action Guides (PAGs) at the Exclusion Area Boundary (EAB) for spectrum of events within and beyond the design basis
- Responsive to Advanced Reactor Policy
- Modular HTGR designs employ multiple concentric, independent barriers to meet radionuclide retention requirements – these barriers comprise the Functional Containment
  - Fuel Elements
    - Fuel kernels
    - Particle coatings (most important barrier)
    - Compact matrix and fuel element graphite
  - Helium Pressure Boundary
  - Reactor Building
- Emphasis is on radionuclide retention at the source within the TRISO fuel coatings
  - Passive core heat removal
  - Control of heat generation
  - Control of chemical attack

Licensing Basis Event (LBE) Selection

- Licensing Basis Events determine when Top Level Regulatory Criteria (TLRC) must be met
- Selected throughout design and licensing process with risk insights from comprehensive full scope PRA that addresses uncertainties
  - Start with deterministic events based on history of related design/licensing efforts; used for scoping studies and early design development
  - As design matures, PRA risk-informs the event selection
- Includes anticipated events (AEs), design basis events (DBEs), beyond design basis events (BDBEs), and design basis accidents (DBAs) (Ch 15 events derived from DBEs with only safety related structures, systems, and components [SSCs] available)
- <u>Comprehensive</u>: Addresses a full-spectrum of internal and external events on a per plant-year basis, including event sequences that could affect multiple reactor modules

NGNP Frequency-Consequence Curve



Design Basis Accident Derivation and Dose Limits

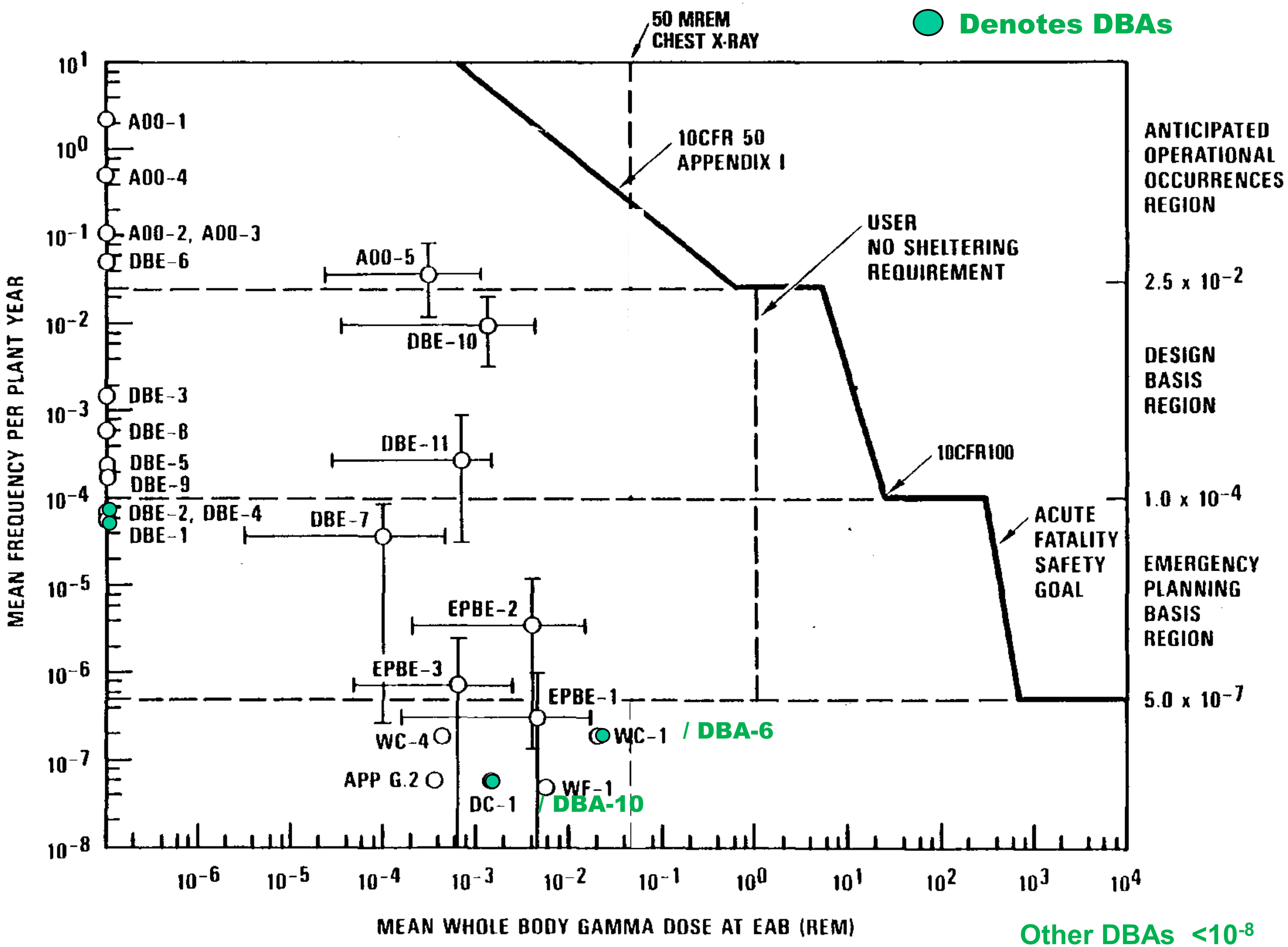
- DBAs (analyzed in Chapter 15 of SARs) are deterministically derived from DBEs by assuming that only safety-related SSCs are available

- The event sequence frequency for some DBAs is expected to fall in or below the BDBE region as a result of the assumed failure of the non-safety related SSCs

- Consistent with regulatory practice, DBAs must meet the DBE dose limits based on conservative (upper 95%) analyses

- DBAs are not derived from BDBEs. Consistent with regulatory practice, BDBEs must meet the NRC Quantitative Health Objectives (QHOs) on a cumulative basis with an expected (mean) analysis

MHTGR DBEs, DBAs, and BDBEs (aka EPBEs) on F-C Plot *(circa 1987)*



Siting Source Term Summary

- The NGNP approach to SSTs is essentially the same as that proposed by DOE in the MHTGR PSID and accepted by the NRC staff in NUREG-1338
- The approach is consistent with discussions of containment function and mechanistic source terms in more recent NRC SECY documents and with approaches previously reviewed by the NRC staff for modular HTGRs
- The approach implements a modular HTGR-appropriate interpretation of the 10CFR50.34 (10CFR52.79) footnote regarding siting evaluation
- Limiting DBAs are evaluated to determine SSTs
- Further, to ensure that there are no cliff edge effects, physically plausible Bounding Event Sequences (with frequencies below the BDBE region), including those involving graphite oxidation, are deterministically chosen and considered

Functional Containment Performance Summary

- Radionuclide retention within fuel during normal operation with relatively low inventory released to helium pressure boundary (HPB)
- Limiting LBEs characterized by
  - an initial release from the HPB depending on leak/break/pressure relief size
  - a larger, delayed release from the fuel
- Functional Containment will meet 10CFR50.34 (10 CFR 52.79) at the EAB with margin, without consideration of radionuclide retention by the reactor building, for the wide spectrum of DBEs and DBAs
- Functional Containment will meet the NGNP design target EPA PAGs at the EAB with margin, with consideration of radionuclide retention by the reactor building, for the wide spectrum of DBEs, DBAs, and BDBEs

Fuel Qualification and Radionuclide Retention Summary

- Fuel Development and Qualification Program is providing data, under an NRC-accepted QA program, necessary to better understand fuel performance and fission product behavior for modular HTGRs
- Fuel program is laying the technical foundation needed to qualify UCO TRISO fuel made to fabrication process and product specifications within an envelope of operating and accident conditions that are expected to be bounding for modular HTGRs
- Results to date are consistent with current design assumptions about fuel performance and radionuclide retention. The program is obtaining additional data to support model development and validation
- Results to date support the safety design basis, including the functional containment and mechanistic source term approaches
- It is expected that operation of the first modular HTGR will confirm the design assumptions

Summary of DOE/INL View on Staff Findings

- The NRC staff has responded to most of the positions requested by DOE/INL in its July 6, 2012 letter (emergency planning position has been deferred)

- The Staff has found most elements of the NGNP licensing approach to be "reasonable" with some caveats

- DOE/INL has concerns regarding uncertainty created by the Staff's positions on Design Basis Accidents:
  - Derivation of additional DBAs from Beyond Design Basis Events
  - Imposition of additional deterministic DBAs with no apparent lower limit on event sequence frequency

Previous NRC Staff/ACRS Positions on MHTGR Low Frequency Event Sequences

Excerpts from MHTGR draft safety evaluation; NUREG-1338 (1989):

- (p 15-7) – "The staff judges that these [bounding events proposed by the staff] results show that the MHTGR has the potential to cope with extremely rare and severe events without the release of a significant amount of fission products"

- Appendix C, (p 4) – ACRS statement: "Neither the designers, the NRC staff, nor members of the ACRS have been able to postulate accident scenarios of reasonable credibility, for which an additional physical barrier to the release of fission products is required in order to provide adequate protection to the public"

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Staff Assessment of Next Generation Nuclear Plant (NGNP) Key Licensing Issues

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
604th Meeting

May 9, 2013

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Office of New Reactors (NRO)
Division of Advanced Reactors and Rulemaking (DARR)

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NGNP Project History and Status

NGNP Project Mission, Energy Policy Act of 2005

- Department of Energy (DOE) and Idaho National Laboratory (INL) will demonstrate by 2021 a prototype modular high temperature gas-cooled reactor (HTGR) for co-generating electricity and process heat
- NRC will have licensing and regulatory authority for the prototype plant

Major NGNP Pre-Application Activities to Date

- NGNP Phenomena Identification and Ranking Tables (PIRT), 2007
  NUREG/CR-6944: Five PIRTs on accident and thermal fluidic analysis; high-temperature materials; nuclear graphite; process heat with hydrogen co-generation; and fission product transport and dose
- Joint DOE-NRC Licensing Strategy Report to Congress, 2008
  <u>Option 2</u> risk-informed and performance based approach: Use deterministic engineering judgment and analysis, complemented by PRA insights, to establish NGNP licensing basis
- NRC assessment of DOE/INL white paper submittals, 2010-present

DOE decision in letter to Congress, October 2011

- DOE will not proceed with NGNP detailed design activities at this time
- NGNP Project will continue to focus on high temperature reactor R&D, <u>interactions with NRC to develop a licensing framework</u>, and establishment of a public-private partnership

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Recent NGNP Interactions

- February 2012 - NRC issued preliminary assessment reports to DOE
  - Assessment of Fuel Qualification and Mechanistic Source Terms (Rev. 0)
    - NGNP Fuel Qualification (FQ) White Paper
    - NGNP Mechanistic Source Terms (MST) White Paper
  - Assessment of Risk-Informed and Performance-Based (RIPB) Approach (Rev. 0)
    - NGNP Defense-in-Depth Approach (DID) White Paper
    - NGNP Licensing Basis Event Selection (LBE) White Paper
    - NGNP Safety Classification of Structures, Systems, and Components (SSC) White Paper
  - Use DOE reimbursable funds to further address framework issues in four key areas
    (1) Licensing Basis Event Selection (2) Source Terms
    (3) Functional Containment Performance (4) Emergency Preparedness
- July 6, 2012 - DOE/INL letter clarified approaches to four key issue areas
  - Public meetings and conference calls between NRC and DOE/INL thru November 2012
  - NRC staff review of additional technical documents submitted by DOE/INL
- January 17, 2013 - DOE/INL briefed ACRS Future Plant Designs Subcommittee on NGNP Activities
- April 9, 2013 - NRC Staff and DOE/INL met with ACRS Future Plant Designs Subcommittee on Assessment of NGNP Licensing Issues

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Three Staff Products for NGNP

1. ISSUE SUMMARY REPORT

New staff report: "Summary Feedback on Four Key Licensing Issues"

i. Licensing Basis Event Selection
ii. Source Terms
iii. Functional Containment Performance
iv. Emergency Preparedness

2. FQ-MST ASSESSMENT REPORT (REV. 1)

Updated staff report: "Assessment of White Papers Submittals on Fuel Qualification (FQ) and Mechanistic Source Terms (MST)."

3. RIPB ASSESSMENT REPORT (REV. 1)

Updated staff report: "Assessment of White Paper Submittals on Defense-in-Depth (DID), Licensing Basis Event (LBE) Selection, and Safety Classification of Structures, Systems, and Components (SSC)."

➢ After ACRS review, staff will finalize products and publicly issue them to DOE

Assessment of NGNP Licensing Issues

MAJOR CONCLUSIONS

- No obvious show stoppers. DOE/INL's proposed approaches to NGNP licensing issues are responsive to NRC Advanced Reactor Policy Statement and generally reasonable, with caveats:
  - Deterministic elements should be strengthened to better align with Option 2
  - Technical uncertainties should be resolved in the NGNP prototype through testing under 10 CFR 50.43(e)(2) to verify core and fuel performance
  - Future interactions on site pre-applicant's proposals for Emergency Preparedness should be supported by specific information on NGNP design, site, and co-located user facilities

QUALIFIERS

- All issues are considered in view of relevant prior staff positions, ACRS comments, and Commission direction (e.g., SECY-93-092, NUREG-1338, SECY-03-0047, SECY-05-0006, NUREG-1860, NGNP Licensing Strategy, SECY-11-0152)
- Staff feedback is advisory. Regulatory decisions will be based on NGNP license application and related Commission policy determinations
- Proposed NGNP approach overlaps with high-level RIPB concepts considered for NUREG-1860, NUREG-2150, and NTTF Recommendation 1. New or revised frameworks resulting from these other efforts may affect staff positions for NGNP
- Proposed NGNP approach is assessed solely for modular HTGR design concept

HTGR Design Evolution (U.S. & Germany) Post-TMI Shift to Modular HTGR Safety Concept

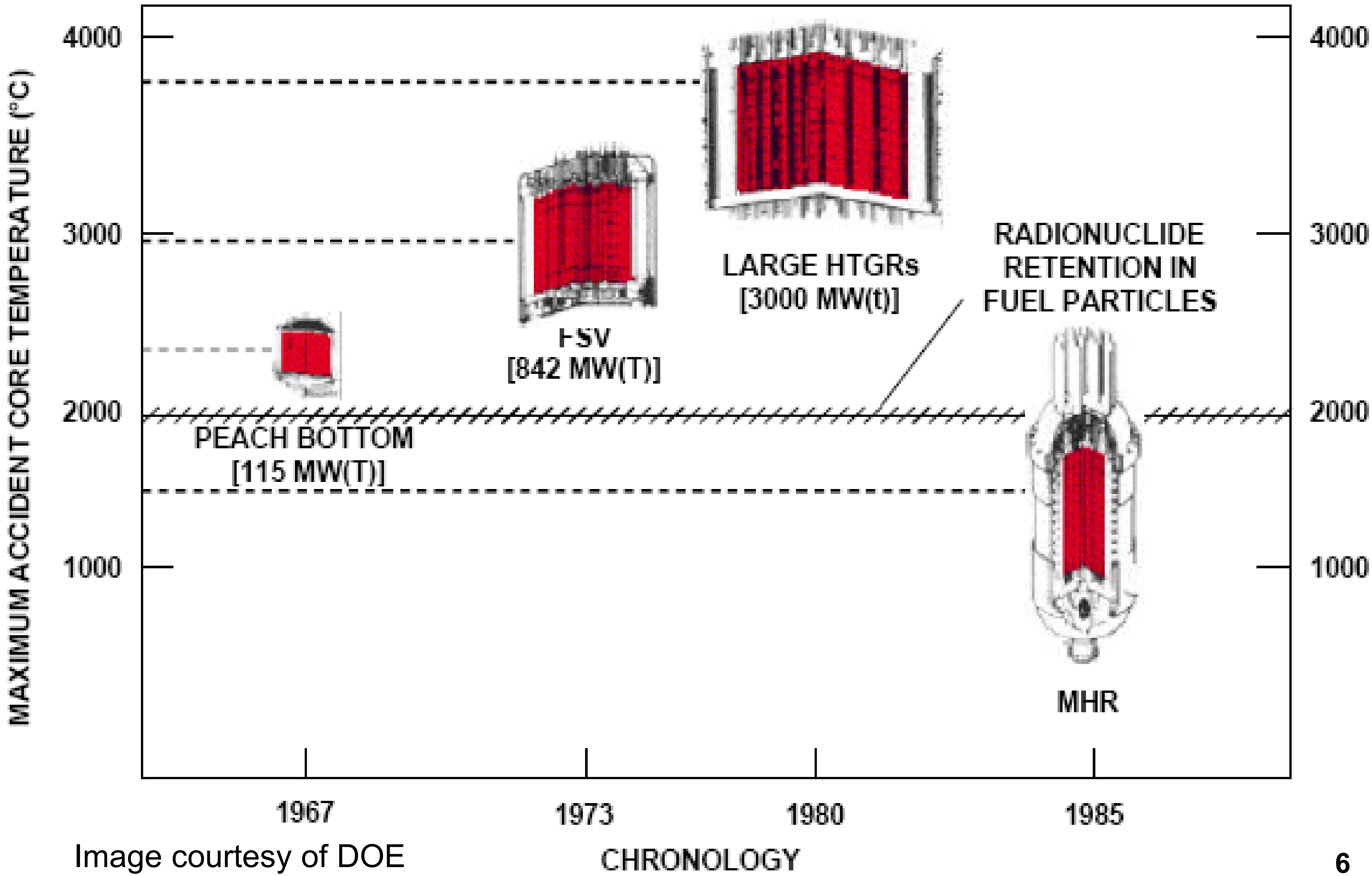


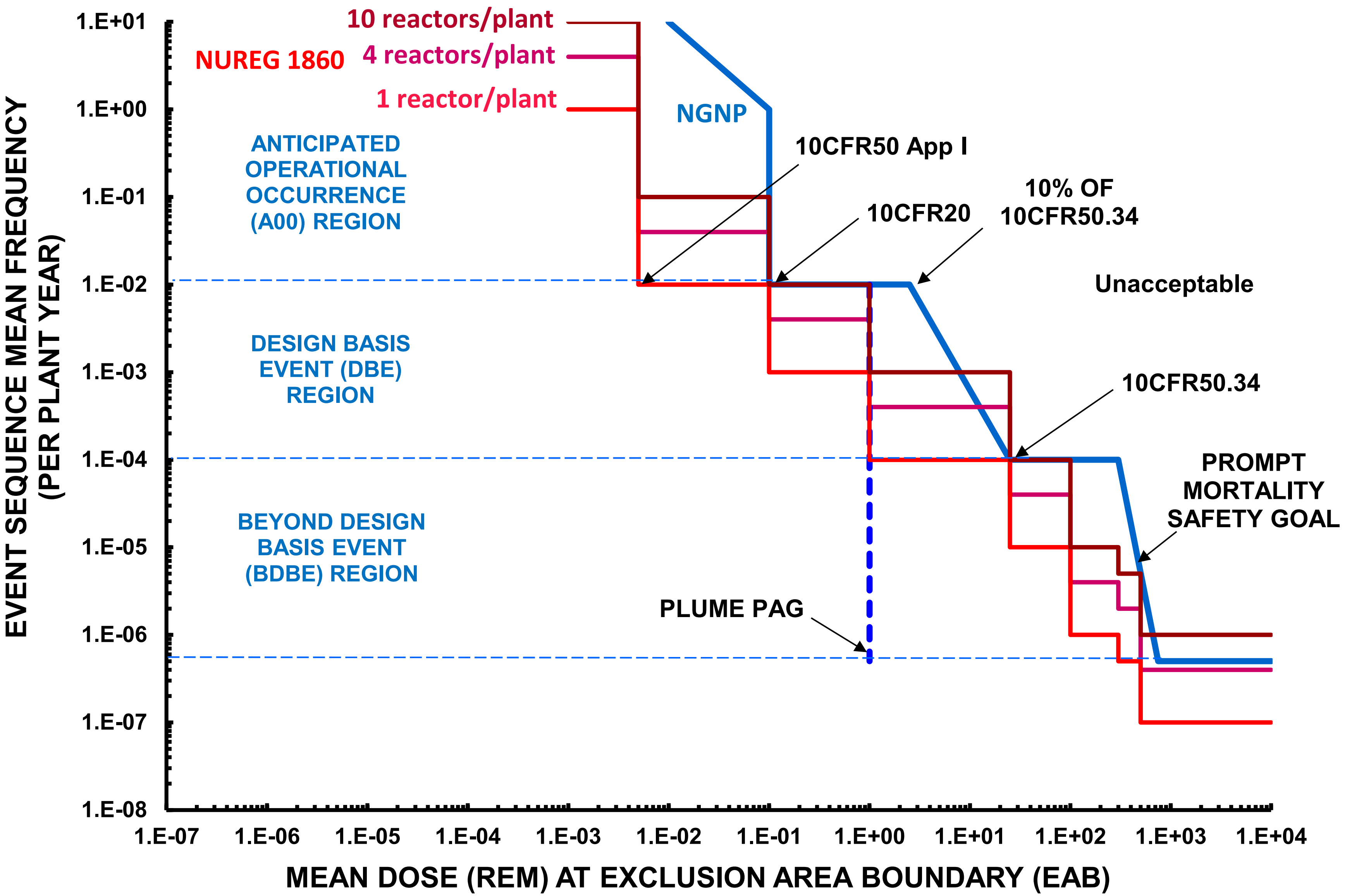
Image courtesy of DOE

LICENSING BASIS EVENT SELECTION

NRC STAFF FEEDBACK ON LBE SELECTION (1/2)

- Proposed selection of TLRC and placement on F-C curve are reasonable. Future NRC policy may consider alternate TLRC and F-C curves
- Proposed "per-plant-year" method is reasonable for addressing risks from plants with multiple reactor modules
- Proposed LBE selection approach is generally reasonable but overly risk-based in some respects. To better align with Option 2, resulting set of LBEs may have to be supplemented:
  - Supplement DBE-derived DBAs with postulated DBAs and DBAs derived from BDBEs
  - Include AEs evaluated against HTGR specified acceptable fuel/core design limits (SAFDLs)
- Proposed DBE and BDBE frequency cutoffs of 1E-4 and 5E-7 per plant-year are reasonable for modular HTGRs if the supporting PRA is full-scope

Comparison of Alternate TLRC and F-C Curves: NGNP Proposal versus NUREG-1860



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Licensing Basis Event Selection

NRC STAFF FEEDBACK ON LBE SELECTION (2/2)

- Proposed processes for assessing LBEs against TLRC are generally reasonable:
  - LBEs are categorized based on mean event sequence frequency
  - LBEs with upper (95%) and lower (5%) frequency uncertainty bounds that straddle event category regions are analyzed against dose criteria for each region
  - Calculation methodology evaluates dose consequences from full event sequences using best-estimate mechanistic source term models with realistic (mean) or conservative (95% confidence) treatment of uncertainties
- Proposed use of realistic source terms for AE and BDBE dose compliance needs further consideration and would involve new regulatory interpretations
- Proposed processes and categorizations for SSC safety classification are reasonable. Special treatments for SR and NSRST are commensurate with ensuring that SSCs can perform required safety functions in LBEs.

MECHANISTIC SOURCE TERMS

Mechanistic Source Terms

NRC STAFF FEEDBACK ON SOURCE TERMS (1/3)

- Proposed definition of NGNP mechanistic source terms is reasonable:
  - Defined as the quantities of radionuclides released to the environment in LBEs, including timing, physical and chemical forms, and thermal energy of the release
  - NGNP source terms are event-specific and determined mechanistically using models of radionuclide generation and transport that account for fuel and reactor design characteristics, passive features, and radionuclide release barriers

  Definition is consistent with ACRS comments and Commission SRMs on staff recommendations in SECY-93-092 and SECY-03-047

- DOE/INL has identified the key fission product transport phenomena for NGNP and has established reasonable plans for evaluating and characterizing those phenomena and associated uncertainties
- Completion of related ongoing and planned AGR Fuel Program activities is viewed as very important, including planned additional activities to better address effects of moisture ingress, air ingress, and dust

Mechanistic Source Terms

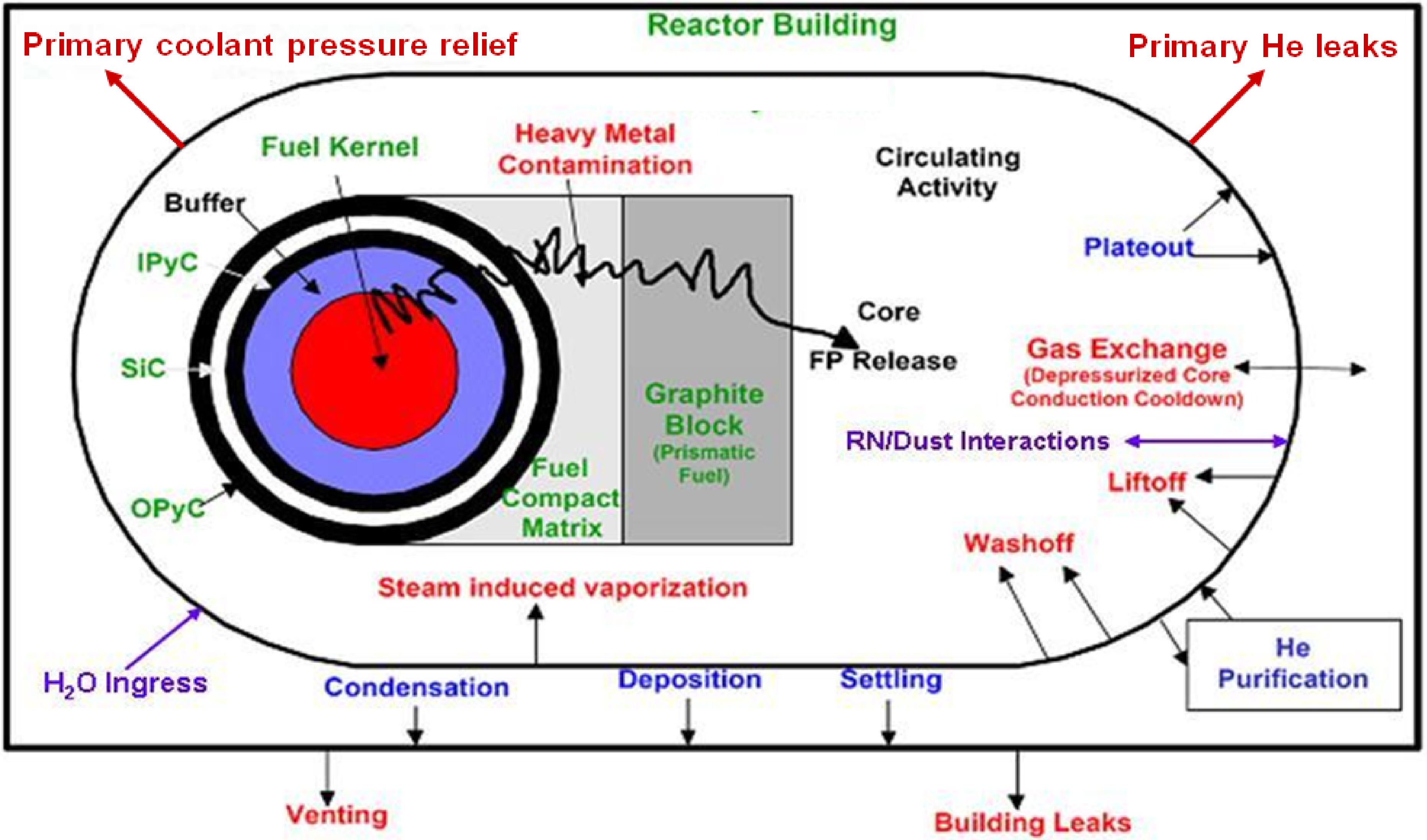

Image courtesy of DOE

Mechanistic Source Terms

NRC STAFF FEEDBACK ON SOURCE TERMS (2/3)

- Prototype Testing: Data from NGNP prototype tests under 10 CFR 50.43(e)(2) would be needed to verify and supplement the technical bases for NGNP accident and source terms analysis
- Likely/possible examples of NGNP prototype testing and surveillance:
  - PIE and accident heatup testing on used fuel discharged from the prototype
  - Mapping of in-core and outlet temperatures during normal operation using either off-the-shelf or novel sensor systems
  - Tests to establish/confirm detection thresholds for plausible core operating anomalies (e.g., core hot spots caused by local obstructions of helium flow)
  - Mapping of core and system temperatures during controlled pressurized or depressurized loss of forced cooling events
  - Tests to further refine/validate selected fission product transport models
- During the prototype testing period, conservative requirements and limits on core outlet temperatures, thermal power levels, trip set points, safety equipment, etc., may be necessary

NRC STAFF FEEDBACK ON SOURCE TERMS (3/3)

- The draft ASME/ANS PRA standard states that all PRA elements (including the mechanistic source terms element) must undergo peer review.
  Such peer review has particular importance for the implementation of risk-informed approaches to NGNP licensing.
- Further consideration of bounding events with air ingress and moisture ingress may be necessary to adequately challenge all available barriers in the assessment of event-specific mechanistic source terms
- In SECY-05-0006, staff recommends that source terms for compliance should be 95% confidence values based on best-estimate calculations

FUNCTIONAL CONTAINMENT PERFORMANCE

Functional Containment Performance

NRC STAFF FEEDBACK ON FUNCTIONAL CONTAINMENT (1/3)

Functional Containment Definition and Performance Standards

- Proposed definition of functional containment is reasonable:

  "The collection of design features that, taken together, ensure that
  - *Radionuclides are retained within multiple barriers, with emphasis on retention at their source in the fuel*
  - *NRC regulatory requirements and plant design goals for limiting releases of radionuclides are met at the Exclusion Area Boundary"*

- Proposed NGNP approach presents a reasonable option for establishing modular HTGR functional containment performance standards (per SRM to SECY-03-0047)
  - Radionuclide containment function: reduce releases to the environs
  - Other "containment" of "reactor building" functions as discussed in SECY-05-0006
    - Protect risk-significant SSCs from internal and external events
    - Physically support risk-significant SSCs
    - Protect onsite workers from radiation
    - Remove heat to keep risk-significant SSCs within design and safety limits
    - Provide physical protection (i.e., security) for risk-significant SSCs
    - Reduce radionuclide releases to environs (including limiting core damage)
    - Limit air ingress after helium depressurization accidents

Functional Containment Performance

NRC STAFF FEEDBACK ON FUNCTIONAL CONTAINMENT (2/3)

AGR Fuel Program Activities

- Overall scope of AGR Fuel Program activities is generally reasonable in context of pre-prototype testing
  - Early AGR irradiation and safety testing results are favorable
  - Completion of planned AGR activities is key for modular HTGR safety case
- AGR Fuel Program should give continuing attention to such areas as:
  - Specification of fuel service conditions for NGNP normal operations and accidents
  - Evaluation and treatment of AGR fuel test irradiation temperature uncertainties
  - Potential needs for additional fuel and fission product transport data for bounding events

Additional data from NGNP prototype testing under 10 CFR 50.43(e)(2) would be needed to provide reasonable assurance of targeted retention in fuel

- Test data on TRISO fuel irradiated in NGNP prototype to more fully address
  - Coating interactions with plutonium fission products (Pd, Ag)
  - Time-at-temperature effects during real-time versus accelerated irradiations
  - Prototypic combinations of fuel irradiation parameters (temperature, burnup, fluence)
- Testing and surveillance to confirm core operating conditions and establish detection thresholds for potential core “hot spot” operating anomalies

NRC STAFF FEEDBACK ON FUNCTIONAL CONTAINMENT (3/3)

Event Selection for Plant Siting and Functional Containment Assessment

- Staff agrees that the substantial core melt accident assumed for LWRs may not be applicable to modular HTGRs
- Proposed approach to event selection for siting source terms is generally reasonable when supplemented with insights from future "safety terrain" studies
  - *Applicant should submit for NRC consideration a risk-informed selection of siting events, building on the types of bounding events considered by staff in NUREG-1338 for MHTGR*
  - *To assure there are no "cliff-edge effects" [credible events with high dose consequences] and to understand ultimate safety capability, bounding event selection should be further informed by exploratory studies of postulated extreme events, including bounding events with air oxidation of graphite per the SRM to SECY-93-092. Such exploratory events should be physically plausible, may have estimated frequencies below the BDBE region (< 5E-7), and will consider inherent behavior of the modular HTGR design*
- Selected siting events should be used as basis for retention requirements of reactor building in functional containment system

EMERGENCY PREPAREDNESS

BACKGROUND ON NGNP EMERGENCY PREPAREDNESS (EP)

- In October 2010, DOE/INL submitted a white paper on "Determining the Appropriate Emergency Planning Zone Size and Emergency Planning Attributes for an HTGR"
  - NRC staff did not formally review this white paper submittal
  - DOE/INL participated in NRC public meetings in 2011 on emergency preparedness framework issues for small modular reactors (SMRs)
  - Stated NGNP goal is to justify Emergency Planning Zone (EPZ) at 400-meter Exclusion Area Boundary

- In October 2011, NRC staff issued SECY-11-0152, "Development of an Emergency Planning and Preparedness Framework for Small Modular Reactors"
  - Described a general approach to scalable EPZs

- 10 CFR 50.47(c)(2) allows EPZ size for gas-cooled reactors to be considered on a case-by-case basis

NRC STAFF FEEDBACK ON EP APPROACH FOR NGNP

- Proposed EP approach is consistent with SECY-11-0152. Staff would be open to considering future proposals by industry or pre-applicants on such topics as:
  - PRA-informed approach that includes accident dose assessment versus distance
  - Risk-informed criteria for determining the point at which the probability of exceeding the PAG values is acceptably low
- Specific proposals from NGNP site pre-applicant should be supported by details of the NGNP design, site, and co-located process-heat user facilities
  - EP approach addressing PAGs must be developed by the NGNP site applicant
  - Graded EP may be different for NGNP prototype versus subsequent standard plants
- Proposals should address considerations specific to co-location and co-generation
  - Co-location considerations and guidance for current LWRs are largely applicable
  - Potential EP-basis events and EP strategies may be influenced by
    - Co-location and external events impacting the site
    - Co-generation issues associated with coupling between modular HTGR plant and user facility
  - Consider different regulatory nexus for reactor and user facilities
  - Expect staff considerations of new regulations, hazards assessments, accident evaluations, and security issues

THANK YOU

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Completion of Generic Issue 189

Susceptibility of Ice Condenser and Mark III Containments to Early Failure from Hydrogen Combustion during a Severe Accident

Steve Jones
Division of Safety Systems
Office of Nuclear Reactor Regulation

Briefing for ACRS

May 9, 2013

Introduction

- Initiation of Generic Issue
- Regulatory Requirements
- Technical Information
- Early Stakeholder Interactions
- Regulatory Analysis
- Implementation Plans
- Verification Activities
- Nexus to Events in Japan
- Conclusion

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Initiation of GI-189

- Risk-Informed Changes to 10 CFR 50.44, “Combustible Gas Control for Nuclear Power Reactors”
  - Specify a severe accident combustible gas source term
  - Remove requirements to monitor and control combustible gases associate with design-basis LOCA
  - Modify combustible gas requirements for Ice Condenser and Mark III containment designs
- In SECY 00-198 (Risk informing10CFR50.44), Staff recommended proceeding with rulemaking on the first two items and processing the third item through the Generic Issue program

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10 CFR 50.44 Requirements (2003)

All Containments:

Mixed Atmosphere

Hydrogen Monitors

New Pressure-Suppression Containments (ABWR and ESBWR DCs):

Inerted

Oxygen Monitors

Adds significant beyond design-basis accidents

New Large Dry Containments (AP1000, APWR, and EPR DCs):

Equipment Survivability Analysis w/100% Metal-Water

<10% Hydrogen (PARs and/or Igniters)

Adds significant beyond design-basis accidents

PWR Large Dry and Sub-Atmospheric (59 OLs):

No Additional Requirements Based on Large Volume and High Design Pressure

BWR Mark I & II (31 OLs):

Inerted

Oxygen Monitors

PWR Ice Condenser (9 OLs & 1 CP) and BWR Mark III (4 OLs):

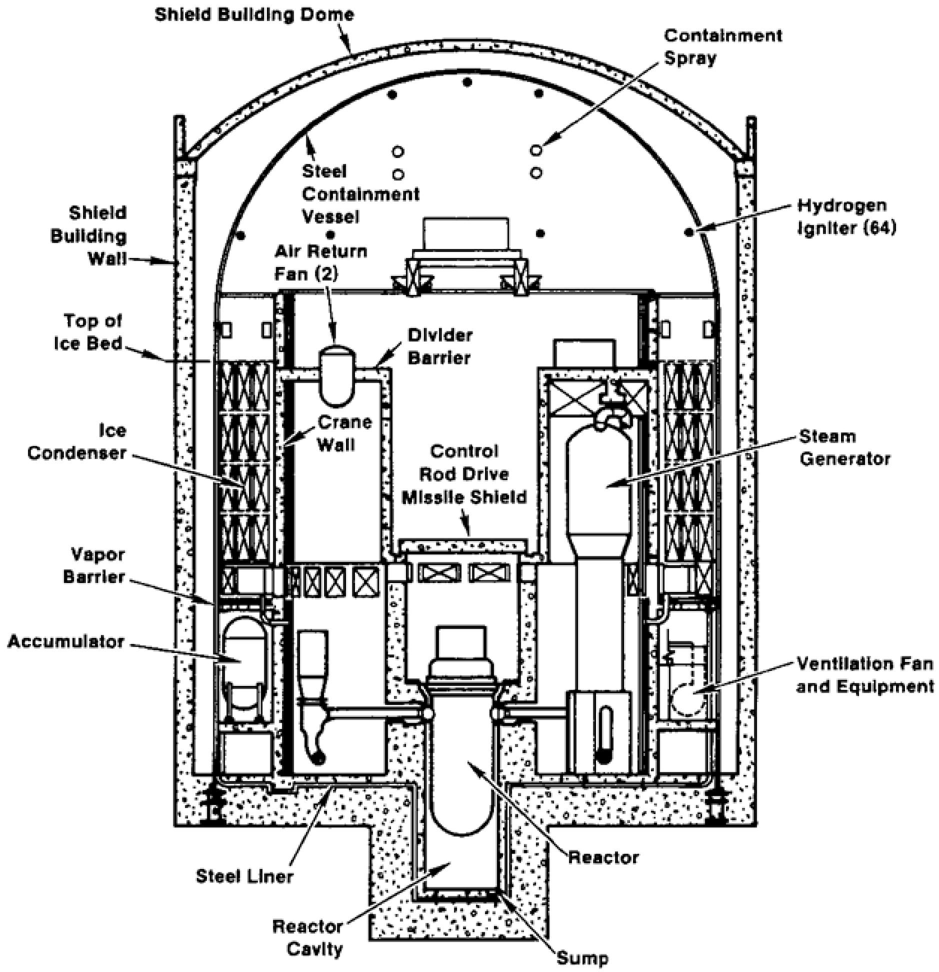
Combustible Gas Control (Existing AC-Powered Igniters)

Equipment Survivability Analysis w/75% Metal-Water (Existing Analyses)

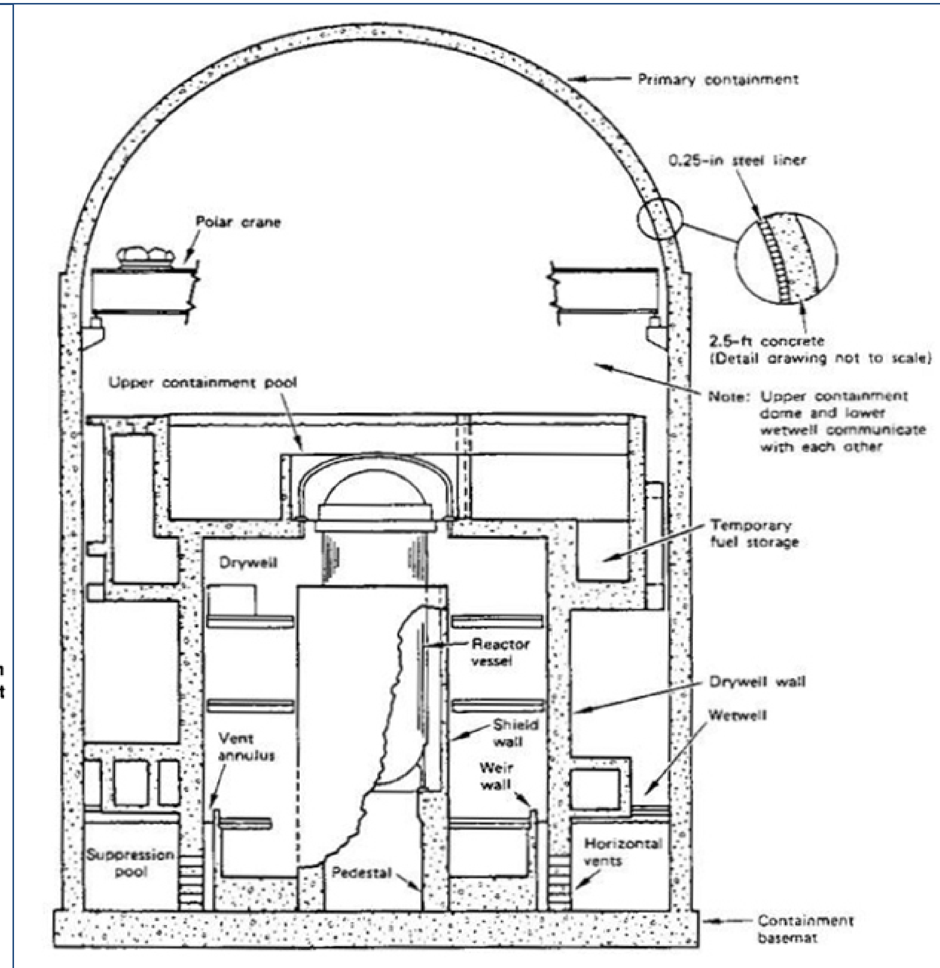
Ignition System Design

- Igniters distributed throughout containment in two trains
- Either train provides full coverage to initiate combustion of hydrogen at low concentrations to limit pressure rise
- Igniters are manually initiated based on emergency procedure direction
- Power consumption is typically less than 15 kW per train

Containment Designs



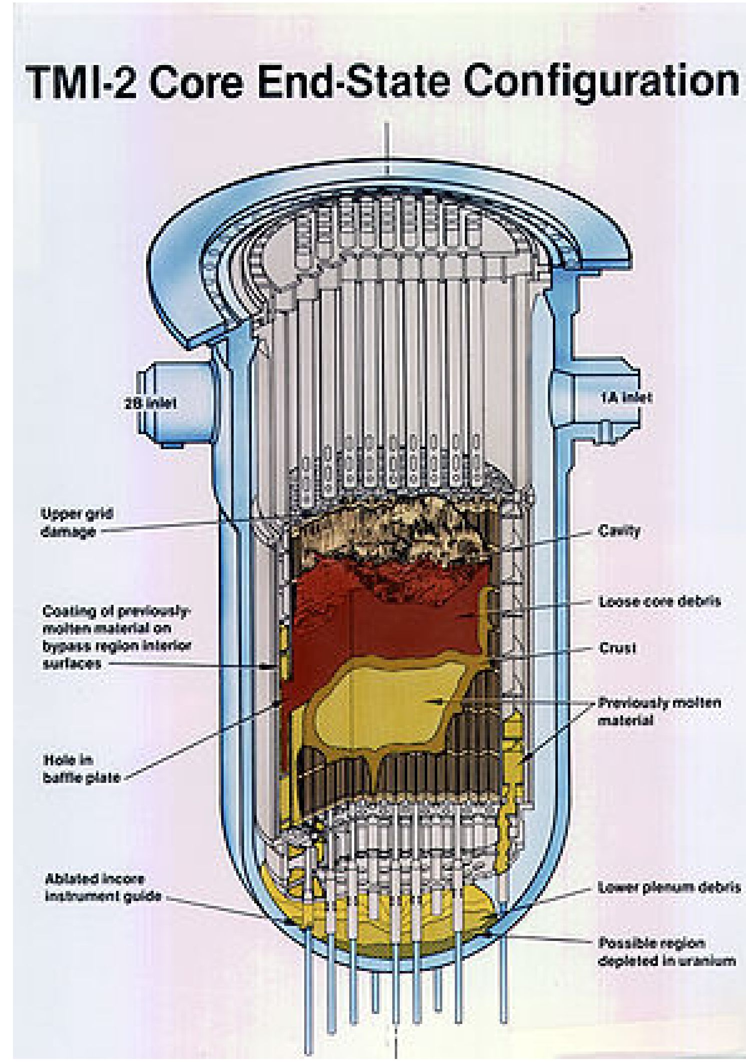
PWR Ice Condenser Containment (Free-standing Steel w/Shield Building – Representative of Catawba, McGuire, Sequoyah, & Watts Bar Units; Cook Units have Reinforced Concrete Containment w/Steel Liner)



BWR Mark III Containment (Reinforced Concrete w/Steel Liner– Representative of Grand Gulf and Clinton Units; Perry and River Bend have Free-standing Steel Containment w/Shield Building)

Technical Background

- Zirconium oxidation by steam at high core temperatures (>1000 C.
  - Cladding Oxidation Damage
  - Production of Hydrogen and Heat
- Heat generation rate from oxidation can exceed decay heat
  - Increased rate of residual coolant inventory loss
  - Increased rate of cladding oxidation
- This feedback mechanism can produce substantial amount of hydrogen in a short time
- Hydrogen released to containment
  - Relief valve operation
  - RCS leaks
  - Deliberate reactor vessel venting



Ice Condenser and Mark III Containment Performance

- Hydrogen could accumulate in containment without operating ignition system
- Conditional containment failure probability (as a result of hydrogen combustion) exceeds regulatory guideline (0.1) for ice condenser and Mark III containment designs
- Mark III containment likely to retain suppression pool scrubbing of releases following hydrogen combustion in wetwell

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Initial Investigation of Issue

- Potential for large early release in absence of igniter function
- Very low frequency event sequence
- Substantial uncertainty in consequence determination
- Considered:
  - Back-up power for igniters
  - Back-up power for igniters and recirculation fans
  - Passive autocatalytic recombiners
- Recommended back-up power to igniters based on relatively low cost and consequence uncertainty

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Interface with Stakeholders

- Staff scheduled several public meetings with stakeholders to:
  - Explain technical issue
  - Describe accident sequences
  - Propose design criteria for back-up power supply
  - Discuss implementation procedures (EOPs vs SAMGs)
- Interface with several organizations, including:
  - Nuclear Energy Institute
  - Union of Concerned Scientists
  - BWR Owners Group

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Discussion Areas

- Design of backup power supply
  - portable verses pre-staged
  - need for design criteria
  - timing for activating hydrogen igniters
- Alternatives to rulemaking
  - BWROG suggested use of Division III EDG to repower igniters
  - PWR licensees suggested use of various on-site DGs as backup power sources
- Benefits and costs

Regulatory Analysis

- Evaluated costs and benefits using plant-specific SBO core damage frequencies and populations
- Considered:
  - voluntary measures and rulemaking
  - PARs, igniter back-up power, and auxiliary equipment
  - containment conditional failure probability (CCFP)
    - Assumed plant-specific CCFPs ranging from 0.22 to 0.97 for ice condenser containments
    - Used CCFP of 0.19 for an unscrubbed release (i.e., wetwell and drywell failure) for the BWR Mark III containments
- Did not fully evaluate:
  - External event and security-related initiators
  - Benefit from enhanced defense-in-depth

Regulatory Analysis Results

- Provision of backup power to igniters adequate
  - PARs substantially more expensive than backup power
  - Mixing fans and hydrogen analyzers unnecessary
- For PWRs, backup power provided a substantial safety benefit at a justifiable cost
  - Most of the benefit provided by proposed voluntary measures
  - Rulemaking not justified after consideration of voluntary measures
- For BWRs, costs of implementing any option were not justified by the increased protection
- Sensitivity analyses did not change conclusions

Licensee Commitments

- Staff continued meeting with affected licensees about security-related issues
- Licensees proposed backup capabilities that provided benefit for security scenarios
  - Catawba and McGuire established permanent power supplies from Safe Shutdown Facility DGs
  - Sequoyah and Watts Bar developed procedures to power igniters from large, portable DGs
  - D.C. Cook enhanced capability to power igniters from large, permanently connected yard DGs
  - BWRs provided portable DGs for local power
- Implementation procedures at the level of SAMGs

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Verification Activities

- Verification procedure established in TI 2515/174, "Hydrogen Igniter Backup Power Verification"
- Commitment implementation and verification inspection completed at most sites by early 2008
- Major modifications at Catawba and McGuire completed at last unit in 2010
- Commitment for backup power at Watts Bar Unit 2 received in 2010
- No identified deviations from commitments

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Nexus to Events in Japan

- Accident progression similar to GI-189 event
  - External event initiated station blackout
  - Core damage with significant hydrogen generation
  - Significant release due to containment overpressure
- Mitigating strategies order includes strategies to maintain containment integrity
  - Hydrogen igniter power for PWR ice condenser and BWR Mark III containments
  - Addresses external event equipment survivability
- Imposes durable regulatory requirement

Conclusion

- Effective measures to control combustible gas during an extended station blackout have been deployed
- Verification inspections have confirmed capabilities
- Agency response to events in Japan will enhance this capability
- Accordingly, GI-189 can be closed