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NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS (ACRS)

SUBCOMMITTEE ON RELIABILITY AND RISK ASSESSMENT

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THURSDAY,

APRIL 20, 2006

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ROCKVILLE, MARYLAND

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The subcommittee met at the Nuclear Regulatory Commission, Two White Flint North, Room T-2B1, 11545 Rockville Pike, at 8:30 a.m., George E. Apostolakis, Chairman, presiding.

COMMITTEE MEMBERS:

GEORGE E. APOSTOLAKIS, Chairman
J. SAM ARMIJO, Member
MARIO V. BONACA, Member
RICHARD S. DENNING, Member
THOMAS S. KRESS, Member
OTTO L. MAYNARD, Member
WILLIAM J. SHACK, Member
JOHN D. SIEBER, Member
GRAHAM B. WALLIS, Member

ACRS/ACNW STAFF:

ERIC THORNSBURY, Designated Federal Official

PANELISTS:

ALAN BEARD, GE

SID BHATT, GE

DAVID HINDS, GE

THEO THEOFANOUS, GE

RICK WACHOWIAK, GE

NRC STAFF:

MARTHA C. BARILLAS, NRR/DNRL

SUD BASU

AMY CUBBAGE, NRR

JIM GASLEVIC

LYNN MROWCA, NRR

BOB PALLA, NRR

LAUREN QUINONES, NRR/DNRL

LARRY ROSSBACH

NICK SALTOS, NRR

C O N T E N T S

P R O C E E D I N G S

(8:33 a.m.)

CHAIRMAN APOSTOLAKIS: The meeting will now come to order.

This is a meeting of the Advisory Committee on Reactor Safeguards, Subcommittee on Probabilistic Risk Assessment.

I am George Apostolakis, Chairman of the Subcommittee. Members in attendance are William Shack, Sam Armijo, Mario Bonaca, Rich Denning, Tom Kress, Otto Maynard, Jack Sieber, and Graham Wallis.

The purpose of the meeting is to begin our review of the ESBWR probabilistic risk assessment. The Subcommittee will gather information, analyze the relevant issues and facts, and formulate proposed positions and actions as appropriate for deliberation by the full Committee.

Eric Thornsbury is the Designated Federal Official for this meeting.

The rules for participation in today's meeting have been announced as part of the notice of this meeting previously published in the Federal Register on April 4, 2006.

A transcript of the meeting is being kept and will be made available as stated in the Federal

Register notice.

It is requested that speakers first identify themselves and speak with sufficient clarity and volume so that it can be readily heard.

We have received not written comments or requests for time to make oral statements from members of the public regarding today's meeting.

We will now proceed with the meeting, and I call upon Ms. Amy Cubbage, the NRR's project manager, to introduce the presentations.

MS. CUBBAGE: Good morning. I'd just like to give a few opening remarks to set the stage for the presentations you'll be hearing from GE today and tomorrow. There will be a staff presentation tomorrow afternoon as well.

The application for certification is submitted in August and then supplemented in September-October. The application was accepted for docketing on December 1st, 2005, and since that time we have received Revision 1 of the design control document in three different pieces as listed here.

The one piece that has not been submitted yet is Revision 1 of Chapter 19 of the DCD, which is the PRA.

We did provide preliminary requests for

additional information to GE on severe accidents. Those were provided to GE in RAI letter number three, which was sent to them in December. That should be '05, a typo there, and GE is in the process of revising the PRA to address these RAIs and also to incorporate the changes that were made between Revision 0 and Revision 1 of the DCD.

So as you can see here some of the chapters of the Revision 1 of the PRA have been submitted and have been provided to the committee. The additional chapters, I believe some of them are coming today and others will be here within a week or two.

At that time we'll have a complete Revision 1 of all the PRA documents.

Just the overall certification schedule. We're currently issuing RAIs to GE, and that will proceed through October '06, and then we're expecting all of the RAI responses to be received through November '06.

We're planning to issue the SER with open items in October '07, and at that point we'll begin the process of closing those open items and issuing supplemental SERs as necessary in assumed 15 months' duration to complete that effort, and then we will start the rulemaking period, which is assumed to last 12 months.

CHAIRMAN APOSTOLAKIS: When you say 15 months, starting when?

MS. CUBBAGE: Starting with the issuance of the SER with open items. So --

CHAIRMAN APOSTOLAKIS: October '07, 15 months after that?

MS. CUBBAGE: Right, and that's just an assumption at this point. Until we know the number and scope of open items, we won't be able to establish a firm schedule for that. If the number and scope of open items is small, we may be able to proceed quicker than that.

CHAIRMAN APOSTOLAKIS: So we may go to 2009.

MS. CUBBAGE: That's right.

CHAIRMAN APOSTOLAKIS: And the ACRS is involved there?

MS. CUBBAGE: The ACRS would be involved. Right. I would expect a lot of involvement at the SER with open item stage, and then as we're issuing the supplements. Of course, if there's any topics of interest early on, we could provide more meetings like this to provide you with an overview of different topics.

So that's all I had.

MEMBER WALLIS: And you said that there are other presenters tomorrow afternoon?

MS. CUBBAGE: Yes, tomorrow afternoon.

MEMBER WALLIS: We're due to adjourn at 12:15. So they may be talking to themselves.

MS. CUBBAGE: I say afternoon. Mid-morning. Sorry. It's noted on your agenda.

And what we are doing, briefly, tomorrow is just going over the RAIs that we've issued, a summary of those, and then Office of Research is going to be presenting information on confirmatory severe accident calculations.

MEMBER WALLIS: Just a core catcher?

MS. CUBBAGE: Is Office of Research going to? I don't know. That is a question for GE.

At this time I'd like to introduce Stephen Hinds to make some remarks for GE.

MR. HINDS: Good morning. I'm David Hinds from the GE ESBWR Engineering Manager.

I'd just like to hurriedly introduce our team that we have here today. We have Rick Wachowiak over here. He is PRA lead. He will be the main speaker today.

And we also have Sid Bhatt over here, who will also be supporting Rick and making some presentations this afternoon.

Supported by Alan Beard, basically if you ask some questions that we need to point in his direction supporting the presentation.

And then coming in later we'll have Theofanous, who will be supporting us on our severe accident analysis.

And we have a day and a half planned here with the focus, overview of our PRA as well as our severe accident analysis, and we'll go I suppose as deep as we can within the day and a half time period, and I'm sure we'll be back here to see you again.

We look forward to sharing information with you here today. The PRA with the ESBWR has been done in parallel with the design and we're going to cover some of that process, but it has been a very interesting process using the PRA as a design tool such that we can incorporate risk insights into the design as we go along. It brings upon certain challenges we're actually closing out and completing in the PRA, but it's a very good design tool and useful in our design process, and Rick will cover that in more detail.

So I'll turn it over to Rick.

MR. WACHOWIAK: Good morning. I guess I'm supposed to sit close to the microphone.

CHAIRMAN APOSTOLAKIS: Do you mind standing up?

MR. WACHOWIAK: I don't mind standing up.

CHAIRMAN APOSTOLAKIS: We want to see your body language.

MR. WACHOWIAK: I'll go ahead and start from here.

The first part of the presentation is going to be an overview of what it is we're going to do today and tomorrow and talk a little bit about the philosophy of how we used the PRA as a design tool, to be able to say. So the agenda for the meeting or at least the GE presentation, this is all printed in the agenda, but we want to cover an overview of how we use risk management. We're going to talk about severe accident prevention, which is pretty much the Level 1 PRA; severe accident mitigation, which discusses the various phenomena of severe accident; containment system performance. Once we get beyond the phenomena of severe accidents, what does the containment do as a system itself?

We'll talk about our off-site consequence analysis as it relates to a design PRA, a non-site specific design PRA.

Tomorrow we'll talk about external events, shutdown, and then conclude with some of our insights and other information about how we'll be proceeding as we go into the future.

The purpose of the meeting, one, to outline the strategy for how we use risk management land ESBWR design. We want to be able to demonstrate to you the robust nature of the ESBWR as it relates to severe accidents and the way we prevent and mitigate severe accidents.

We're also going to talk more about how we use the PRA as a design tool for designing and also for licensing nuclear power plants.

Now, in the DCD phase of this whole design, which is what we're discussing now, we have to build a PRA that will support the design that goes in and is being reviewed for the DCD, and we needed to do certain things. We can't do everything at this point because we don't know everything at this point, and we may never know everything, but we get closer as time goes by.

What we want to make sure we can do is that this PRA needs to be able to demonstrate that we meet the established goals, risk goals. We want to be able to demonstrate that the ESBWR design is actually better than what's currently out there. So not only meeting the goals, but we want to meet and exceed the goals. It's hard to say with goals which way is exceed.

Also in this process, we're extending the use of defense in depth into the severe accident scenarios themselves, and we'll talk about that on a later slide. We want to be able to identify systems that are important to risk and provide a basis for the design reliability assurance program.

Those two things are some things that are going to be a constant dialogue with the NRC over the DCD process because some of the things that you need in order to identify what goes into these pieces are not necessarily available to go into the analysis at this point.

So we have to figure out how we balance what we know at this time in the design versus what we think it's going to be in the future and what controls need to be placed on how we address these things in the future. I think that's going to be a constant dialogue, and it's not settled business yet.

Finally, we want to be able to provide a framework for the plant specific PRA. In the end as we go through all of the iterations for the PRA during the design phase, during the licensing, the ultimate output is going to be something that the utilities can use in their operation of the plant. And because it has gone through the licensing phase, it will be something that the NRC is familiar with, unlike with the current plant PRAs where there was kind of, you know, the plant guys knew some things, the NRC knew some things, and nobody quite matched up.

But we should all be in sync when we get through this process here.

MEMBER DENNING: Before you move on from this slide, when you talk about demonstrating ESBWR meets established risk goals, by that do you mean the quantitative health objectives?

MR. WACHOWIAK: Yes, and the CDF and log release frequency goal.

MEMBER DENNING: Right. Have you established goals yourself that are more stringent than those goals or different than those goals?

MR. WACHOWIAK: In some cases we have, and it is kind of built in down here. Demonstrate that it's better. Let's take the core damage frequency goal. The subsidiary goal is established at ten to the minus four per year.

Well, the EPRI URD took that down another level, ten to the minus five per year. We still don't want to be in that range. We're looking at below ten to the minus six for all the things that we know about. We're trying to do as good as we can to be below ten to the minus seven for the things that we know about at this point, and we think we've established that.

But those are not -- below the ten to the minus six, it's more of a squishy goal rather than a hard goal. We want to get there, but that's how we're using the PRA to drive us toward that range.

And once again, remember that where we are now with knowing what we know at this current phase of the design, if our target is below ten to the minus seven, as things come up we have room to address them and room to see how we want to proceed with those.

CHAIRMAN APOSTOLAKIS: Which is exactly the point I wanted to raise. I mean, you can't demonstrate that you need to establish goals because your PRA is necessarily incomplete, correct? I mean you can afford three orders of magnitude below, chances are you will meet it, but at this point, I mean, we have got knowledge that there are, you know, many holes in the PRA because you don't have a plan.

MR. WACHOWIAK: I would agree with that.

CHAIRMAN APOSTOLAKIS: I mean, you need a fire assessment. Every other sentence says, you know, "We don't have information. This is generic. This is generic. We don't have information," which is fine. I mean, that's the situation, but we can't really say that we're demonstrating we're meeting the goals. I mean, we're doing what we can with what we have now. Of course, if we violate the goals now, we are in trouble.

So do we have the microphone finally? Ah, there you are.

(Discussion was held off the record.)

MR. WACHOWIAK: All right. One of the things that was associated with this demonstration, one, you really can't demonstrate until you're done and you know everything that you don't know now, and even when you get to that point, there's still the unknown unknowns, and you'll never get all the way down. But we're talking about demonstrating using what we know now.

There are also cases that we looked at and we know that we need to know more information to get to there, and so what we've done in our process is we've specified some design requirements that says, okay, the analysis is going to assume in the fire area it's a fire thing, but it's really in the flood scenario. We're going to specify where some of the fire protection piping needs to be in the control building because we want to assure an assumption that we put into the flooding analysis. So we're providing design requirements out of the PRA to address some of these unknowns at this point.

MEMBER WALLIS: Does your PRA include deliberate human actions in some way?

MR. WACHOWIAK: Acts of commission?

MEMBER WALLIS: Yes. Do you have it so that it's robust in terms of acts of commission?

MR. WACHOWIAK: The current design phase, the current DCD PRA does not include acts of commission.

MEMBER KRESS: There was some explanation for that, having to do with the fact that no operator actions are required for 72 hours or something.

MR. WACHOWIAK: No operator actions are required for 72 hours, but we have to remember that no operator actions required doesn't mean no operator actions will happen. But the way that our goal is in designing the control systems of this passive plant is that if the operators start to do something and then they stop, the plant should move itself back into the stable state as opposed to where in some of the acts of commission and existing plants, where operators start getting into things they send down a different path and it gets kind of unknown.

What we're trying to do with this design is make it so that if they do something, recognize that they're going the wrong way and go hands off again, it's supposed to stabilize back into the safe, stable state condition. We're not far enough along in the design of the control systems to be able to prove that, but that's the goal that we have in mind.

The scope of the DCD PRA for internal events at full power, we've got Level 1, Level 2, and Level 3, and you have to recognize Level 3 is not a real Level 3. It's a Level 3 using imaginary information provided to us in the URD for population and things like that. And we really only look out about ten miles from the site boundary in addition to that. So it's maybe a three minus.

Internal events. For shutdown we've done Level 1 and in the process of completing a simplified Level 2, which is going to be in one of these submittals here that will come up shortly.

External events. We've done internal fires, flood, and high winds. As you said, on what we believe is a conservative bounding basis, once again, the details to do a detailed analysis of these are not here yet.

Seismic margins on the safety systems we've provided, and all of this is associated for the internal events at the Level 1, and we've covered in the internal fire and flood both full power and shutdown analysis. So that's also the initial Rev. 0 that you may have seen didn't have the shutdown for fire and flood in it. We've completed that analysis, and we are in the process of writing that up, and we'll talk about it a little tomorrow when we get to the fire and flood, but you don't have those documents yet.

Okay. Let's talk a little bit about the extended defense in depth. Historically the classical design and analysis work that was done for previous plants provided defense in depth certainly, but it was using the design basis or single failure type of assumptions.

For an accident you have an accident under the parameters and a single failure, and then you make sure that you have defense in depth associated with providing the fuel barrier, providing the reactor coolant boundary barrier, providing the containment barrier, still under that whole same framework.

Here what we've done is we've moved that on into the severe accident arena where we're looking at multiple failures of maybe components within the same systems or components across barriers, and looking at how we can provide defense in depth against things that went beyond what were looked at before.

And I kind of say this in that the main objective is to address common cause type failures. I'll get to the sub-bullets here in a second.

We also look at defense in depth on the containment side, not only given a degraded core that's still in the vessel, which was historically done for defense in depth, but now we're looking at what kind of protection we have for core in the floor type scenarios, and we'll get to some of those later this afternoon and talk about the areas where we've addressed that.

Now, one of the places where we're using the PRA as a design tool is in this area of the extended defense in depth. How is it that we can protect against some of these multiple failure scenarios?

Historically when a plant came across some common cause failure issue, the only option it really had was to do an augmented QA, if you will, on those components that you may see common cause failures there.

Well, we are in the design process. We have the luxury of doing something else in addition to that and adding diversity to our systems to try to eliminate some of the common cause or eliminate the effects, strong effect, of some of the common cause failures, and that's something that because we're using the tool this early, we can cost effectively provide that.

CHAIRMAN APOSTOLAKIS: Are you coming back to this issue later?

MR. WACHOWIAK: I didn't have any specific bullets on that. So --

CHAIRMAN APOSTOLAKIS: Well, it would be nice to see an example.

MEMBER DENNING: Specifically what were you looking for, George?

MR. WACHOWIAK: A specific example?

CHAIRMAN APOSTOLAKIS: Yeah. I mean, --

MR. WACHOWIAK: You know, actually in the next presentation I do talk about how we use a combination of passive and active systems and diverse control systems. So I think I have an example there. So we'll get into that.

MEMBER ARMIJO: But was that an output of this process or was that already going in and you had planned to do that? In other words, are you really using the PRA to gain insights that will help you create diversity that pays off?

MR. WACHOWIAK: The answer to that is most of the time. Because there are other things that are in the we'll say the different requirements documents that are out there that say, well, you've got to look at diversity.

MEMBER ARMIJO: Right, generally speaking.

MR. WACHOWIAK: So if we hadn't done a PRA, we probably would have gotten there anyway, but in general, those documents to some degree came out of previous risk analysis. So it's kind of in there.

However, where we are doing this is when we say -- when we look at what the PRA is telling us. Here's a common cause failure that we need to address. We go back and we say, "What kind of diversity do we have in the design to address things like that?"

And especially in the instrument and control system area, we did use the PRA to define which instrument and control systems themselves needed to be diverse from the other instrument and control system.

MEMBER KRESS: How did you quantify the effect of that diversity? Did you change the beta value?

MR. WACHOWIAK: Basically, that's what we did.

MEMBER KRESS: But you had no way to know what to change it to?

MR. WACHOWIAK: At this point in the design and procurement, yes, it was looking conceptually.

MEMBER KRESS: So you use expert opinion or something?

MR. WACHOWIAK: Expert opinion. Conceptually what would the effect of using diverse control systems have on this, and conversely, what was the effect of saying that we don't need that diversity requirement here? What would that do to us in terms of our design PRA?

Yes.

MEMBER SIEBER: I was going to ask a question about diversity in the INC area. My question really goes to the extent to which you use diversity.

For example, in the digital INC scheme, you could have diversity in computer, here's Train A, here's Train B, here's Train C. But they could all use common software, which sort of defeats the principle of diversity because if there's a mistake here and you replicate it over here, a mistake in both places and it will fail both places.

To what extent have you fleshed out the degree to which diversity would be required not only in higher order, but also in software and techniques, databases, et cetera?

MR. WACHOWIAK: We've looked at basically all of those types of issues. We are specifying the two INC systems need to be diverse. What we mean by diverse there is different hardware platform, different vendor. I think it would be different vendor, different operating system in some case. It's going to be different -- I've already covered hardware.

So we did address those things. Now, is it possible that some of the different diverse INC systems could have some overlap? And the answer there is yes.

But the question then is: where is that appropriate? Where we are in the design phase on that right now is we've got, if you will, a diversity matrix that the INC guys and the procurement guys are looking at, which is the kind of diversity we want to have in this system, and they're in the process of evaluating different vendors under a multitude of different criteria, including the diversity criteria, to try to assign the correct vendor system hardware for each of those different systems, and that's ongoing at this point.

MEMBER SIEBER: When you finally certify ESBWR, will the INC portion be included in that certification, or would that be done at the COL stage?

MR. WACHOWIAK: I guess that's --

MEMBER SIEBER: Or don't you know?

MR. WACHOWIAK: I'm going to have to defer because those are policy decisions, and I don't get to make those.

MEMBER SIEBER: Well, make it, you know.

(Laughter.)

MR. HINDS: Hi. This is David Hinds.

As much as possible, the INC system is part of the certification, but we are using the DAC approach, or design acceptance criteria approach, but we're moving as rapidly as possible to close as much of the DAC or design acceptance criteria open issues, and it will be flowing through certification and some of it into COL as well.

But the major issues that affect, I guess, the essence of your question and diversity, we intend to close that as soon as possible, but we did take the back-up approach. So some of that is going on as we speak.

MEMBER SIEBER: I can see why you would do that, because if you specify today what you would do by tomorrow, it would be obsolete.

MR. HINDS: That's the reason for the DAC approach. The design acceptance criteria, for anyone that's not aware of what I'm speaking of, defining the design in the form of a criteria as opposed to just the end result of we selected this piece of equipment because, as you say, the INC system has become obsolete rapidly. So we're defining the criteria, and then as rapidly as we can we're filling in details that can help us to firmly answer questions such as this, the defense in depth, although we have to maintain a certain amount of flexibility due to obsolescence of software and hardware, and that's the balancing act we're working with in the INC system.

MEMBER SIEBER: Okay. Thank you.

MEMBER DENNING: Stay there just a second because you may prefer to answer this question, and that is from your perception, what are the regulatory implications of this extension into the control of severe accident processes? Specifically, I'm wondering about things like as far as the core catcher is concerned where there might be a lot of phenomenological uncertainty that could affect our perception of what the probability of failure that is.

I mean, it's possible that you could say, well, it doesn't need a high confidence or a low failure probability because we've got a lot of margin in our risk space. Whereas, our perception of safety systems from the conventional view is that they have to have very high likelihood of success.

When you get into the domain of core catchers and things like that, from a regulatory viewpoint, what kind of criterion do you think are in front of you? Do you have to really demonstrate with high confidence the core catcher will work or is it really just an element of defense in depth?

MR. HINDS: Well, I guess I'll start and let Rick get into more details, but my view on devices such as that is that it is very much an extension of the safety of the plant and taken into another step beyond where the current generation of plants are. So you certainly can make I'll say a somewhat valid argument that the reliability of those systems because they're much behind the front line as opposed to the typical safety systems which are in the plants today front line systems, that the reliability would be different.

Rick, if you want to jump in there as far as probability and any discussions you have related to reliability and probability of the core catcher or the BiMAC.

MR. WACHOWIAK: Right. At this point in time what we have said is that the BiMAC itself, the core catcher for those who haven't seen the future presentations here, we believe that it's a non-safety component. At this point it will be treated as a written system, which means that we will have some kind of reliability controls or availability-reliability controls on it. That hasn't been defined yet, what needs to be controlled.

Now, I think your specific question gets to the uncertainty of the phenomena of how this device, which effectively nobody has seen before -- what's the confidence that we have that it's going to work, and how much confidence do we actually need to have to show that it's going to work?

And I'm trying to think if we have this anywhere else in the presentation. I know I don't have it in one of mine. Theo may have it there.

We want to remember that the BiMAC itself was added to the floor of the containment because chiefly to address an uncertainty. In the previous ALWR design that GE had, ABWR, we showed that at least at that point in time, we showed that if we could get water on top of the core in the lower dry well and it was spread to a large enough degree, that we would be able to prevent continued core concrete interaction and prevent the base MAAP penetration by the melt.

There have been uncertainties associated with that. I don't think that that point has been refuted, but it's just not certain whether that's going to happen in all situations.

So what we've done is we've added the BiMAC as another layer of protection to address that kind of uncertainty. So does the BiMAC have to be perfect? Well, it doesn't change the fact that the floor and spreading is still there, and we should still in most cases be able to cool pool the corium from the overlying pool, but it's there mainly to address those areas where we're uncertain if that was going to work.

So to get back to the point, it's not there as a replacement for what was done in the past. It was there to augment what was done in the past. So for that matter I see it as an augmentation, and we don't have to be 100 percent certain. We should be able to show that within a fairly large band of certainty, this is going to be a good design.

Does that answer your question?

MEMBER DENNING: Not totally, but I understand.

MEMBER WALLIS: I'm not sure it does because you're sort of qualitative, but your PRA says it's going to work with 99 percent effectiveness. That's a pretty high effectiveness for something that's so unusual

MR. WACHOWIAK: Okay, and we'll talk about that in the presentation after lunch about how we determine that 99 percent effectiveness. Based on our evaluation and calculations, we think it's better than 99 percent, but we've backed off on that mainly for the purpose of -

MEMBER WALLIS: How many tests did you do to verify this?

MEMBER SIEBER: Only one.

MR. WACHOWIAK: That being said, when we

said it was 99 percent effective, you also notice that in there we didn't really even address, you know, what if it's not there. How effective would the containment be if it's not there?

And in one of the upcoming chapters unfortunately that you don't have yet, we will specifically be answering that question.

CHAIRMAN APOSTOLAKIS: Can we go on?

MR. WACHOWIAK: I think so.

Okay. I think we've talked about this quite a bit,b ut let me emphasize in using the PRA as a design tool, our thoughts are we want to eliminate severe accident vulnerabilities. We want to make sure that these things aren't built into the plant up front. We want to get them out as we see them.

So this provides us a systematic way of doing this, not just guessing at what might be a vulnerability. We actually go through and look for the vulnerabilities and address them in a systematic way.

MEMBER WALLIS: Now, does it play a more important role than DBAs? I mean, could we do away with DBAs if we used PRAs as a design tool?

What's your experience?

MR. WACHOWIAK: I think that we're

addressing things in different ways. We would have to do probably more things in the PRA or maybe move some of the same things that we had been doing in the DBA analysis into the PRA if we tried to do that. So at this point we start in the PRA with everything we know from the DBA analysis, and we have that as a given that it's going to work that way.

And it starts us at a good point, good starting off point to go and do a robust analysis. If we did away with all of the DBA analysis, we wouldn't be starting on as firm a ground with the PRA, and we would have to add a lot of that back in. So I'm not sure from our point of view, from the design point of view, what kind of relaxation that would give.

On the licensing side, that's up in the air. You know, as long as you see the analysis, then maybe you have confidence in what we're doing. So we're not proposing to eliminate the DBA analysis at this point in time.

We've talked a little bit about this. As a matter of fact, most of the questions this morning have come up. On the effectiveness of using this to eliminate vulnerabilities, if we don't know everything we need to know to remove vulnerabilities. As anybody who has done PRA knows, the details tend to be where you find issues that haven't surfaced before because we're not looking at a simple single failure sort of thing. We're looking at multiple failures and interactions among multiple components that could cause multiple failures, and typically those kinds of things aren't in the details.

However, we think we've addressed through the way we apply common cause and some of our sensitivity analyses to identify potentials for these failures might be, and we think we have addressed that through adding different diversity requirements and also other design requirements that come through as we proceed.

That said, the next bullet makes it very attractive to do this because at this point if we can identify things before we actually have them designed, especially before we have them constructed, it's much easier to correct things that we would determine.

In the end, an imperfect tool is better than no tool at all, better than guessing, and we think that as long as we apply this in a prudent manner, we're not going to take things way overboard, but we are going to find a number of vulnerabilities that have been identified without using the tool.

On this next page, I just want to give my perspective of where things are and how we deal with the PRA in a design that is proceeding in parallel.

On the conceptual design block down in the end, what we're really trying to say is is the design feasible. We don't really have a lot of actual design. We've got concepts of how systems might work.

When we're applying a risk assessment in that manner, we're really doing it qualitatively. What kind of redundancy are we doing to need, do we think we'll need for this system? Should there be diversity applied to some of these things? It's all in a qualitative sense.

And we're looking at defense in depth at the conceptual level. Pretty much it's based on what was found in the past. What problems did we have with previous plants, and what don't we want to have problems with now?

As we move to the next phase where I believe we are now in the qualitative design base or the DCD phase, the questions that we're trying to answer here are can this design be licensed. Okay.

We've specified most of our major components. We now are at the point where we can do a combination of qualitative and quantitative PRA to address specific things, defense in depth between systems. We can apply common cause factors, but we're still in the qualitative range for some things like in the fire and flood type of analyses, seismic type analysis.

We think that we can eliminate sequence type vulnerabilities, things that would be the big hitters, if you will in the final PRA.

As we move through the detailed design, this question comes in the later part. Will it be licensed? Do we have enough information for this thing to be licensed?

By then we believe that we'll have the components specified. We'll be able to do a quantitative PRA, albeit with gaps. We won't have detailed evaluation of the humans that aren't trained on the systems yet. We won't have plant specific data. We won't have some of the things that are being looked at in the current PRAs.

I call this system level vulnerabilities eliminated, but it's really just more of a progression till we can do more with it.

By the time we get to construction, we end up with all of our components not actually just being specified, but being described. We can do more detailed PRA, and finally get to the point where we think we've addressed things.

I get to the hypothetical out in the last column here. The plant is in operation. All of the components are described again. They all needed to be described before here, but what I'm just mainly trying to get at with this next slide is that we are still working on the PRA even after the design is done, and so --

MEMBER WALLIS: Well, by described, you mean their performance has been quantified. "Describe" is a very vague term. You mean you actually got a measure of how they will perform.

MR. WACHOWIAK: Yeah, I kind of put that into this block, but, yeah, the performance is known.

MEMBER DENNING: At the construction design level there, where is it to become a site specific PRA, and where's the hand off to the utility in your concept here?

MR. WACHOWIAK: In my concept, somewhere in here is where the COL application occurs and now this is being debated, but you know, some say it's here. Some say it's here, but at the COL application, it becomes a site specific PRA. That still has some of these issues associated with it. It's not till you get to this construction level where you're actually saying, "Okay. This is what's there. We've seen it. We know how it's going to -- you know, we know what the field routing was. We know what the fragilities are."

At that point that's kind of somewhere around here. The hand off to the utility we're looking at right here, but we're bringing the utility people in all along through that whole process so that what we give them meets their needs.

MEMBER WALLIS: So the PRA that we have seen is where on this picture?

MEMBER SIEBER: The second column.

MEMBER WALLIS: It's qualitative?

MR. WACHOWIAK: Qualitative and quantitative.

MEMBER WALLIS: It tends to be very quantitative. It makes some assumptions and some bounding things, but I don't know whether it has much of this qualitative. I'm not quite sure what a qualitative barrier is anyway.

MEMBER SIEBER: Since you don't know what the components are.

MEMBER WALLIS: Very simplified, but it's still quantitative.

MR. WACHOWIAK: Yes. That's why I put

down as a combination there of the two.

CHAIRMAN APOSTOLAKIS: Quantitative means what?

MR. WACHOWIAK: Qualitative means that there's judgment applied to major areas. So, for example, in the fire area we've said, okay, we don't know where the routing of the cable is. We don't know what the heat loads from a specific cabinet is going to be, things like that, but we do know from past designs that if we confine our cables to where the design drawings say they're supposed to go and we put in typical types of cabinets that have been used in plans before, we'll get this type of performance.

And so we qualitatively bound that and used that as an input to the fire risk analysis.

CHAIRMAN APOSTOLAKIS: Maybe a better word would be something along the lines of "significant assumptions made" or something. But qualitative is a red flag for a log of people. Okay? And it's not your fault, and it doesn't really mean anything. Your explanation was really something else, that you have to make major assumptions because you don't know.

MEMBER WALLIS: Simplify it. Simplify it as much as --

CHAIRMAN APOSTOLAKIS: Well, actually

significant assumptions I think or something along those lines.

MEMBER WALLIS: Qualitative to me means all waffle, and it's good enough or some sort of vague statement.

MR. WACHOWIAK: You know, I don't even think we're at the it's good enough in the first column. You know, there's other significant judgments and --

CHAIRMAN APOSTOLAKIS: Major --

MR. WACHOWIAK: -- thing are made, you know. So I guess maybe it's a way of thinking about it.

CHAIRMAN APOSTOLAKIS: Yeah, I wouldn't even call it judgment because judgment is everywhere. It's the assumptions. It's the magnitude of the assumptions that is different. So we need a better word.

The statement is no defense in depth issues is not quite right. You probably mean design, a new wall or something, but defense in depth, I mean, it could be a problem, right, that is imposed? And that problem can be posed even when the plant is in operation. And that's in the name of defense in depth.

MR. WACHOWIAK: Right, and --

CHAIRMAN APOSTOLAKIS: So you mean design defense in depth issues are a result at that point.

MR. WACHOWIAK: I'll go with that.

CHAIRMAN APOSTOLAKIS: Well, I mean, you don't have to go with that.

(Laughter.)

MR. WACHOWIAK: I agree with that. Somewhere along in this phase here we do address which programmatic issues we're going to use, but that's not the --

MEMBER ARMIJO: The design is frozen. The design is finished.

MEMBER SIEBER: In the seismic area, there is a point where somebody does detailed design of hangers and supports.

MR. WACHOWIAK: Yes.

MEMBER SIEBER: Where is that in that chart? Matched to the right or there?

MR. WACHOWIAK: That's in the middle column somewhere, I believe.

MEMBER SIEBER: So everything is going to be precalculated and predesigned and no fit in the field kind of --

MR. WACHOWIAK: That's the intent, yes.

MEMBER SIEBER: Okay. Well, the old plants, all the small and medium bore piping was fit in the field kind of.

MR. WACHOWIAK: Right.

MEMBER SIEBER: That's why we went and had 700 modifications.

MR. WACHOWIAK: The engineering schedule that I work from has those activities in those to complete.

MEMBER SIEBER: That's where it will be, right.

MEMBER ARMIJO: Where do you expect to be for a certified design? When do you think? Is it a detailed design? At what point is this thing ready to be certified?

MR. WACHOWIAK: This is one of these things where I'm not sure that anybody has actually settled on that yet, but it's --

MEMBER SIEBER: It's going to be between these.

MR. WACHOWIAK: It's between these two columns. If you talk to our friends at NEI, they say the beginning of the second column.

MEMBER SIEBER: No, tell them no.

MR. WACHOWIAK: It's just I think there's differences of opinion on that, and we're settling in where it is. We certainly know that it's going to be at least in this column here because that's what we're submitting for certified designs.

Through the design work, we're getting into this phase now. So it's somewhere in there.

MEMBER SIEBER: You will be between the two, between the design basis.

MEMBER KRESS: Tell me. Do you see any value in Level 3 PRA in the design certification stage? Now, be truthful.

MR. WACHOWIAK: With the order of magnitude of frequencies and releases that we're looking at here, no.

MEMBER KRESS: It's just not going to happen, is it?

MR. WACHOWIAK: We're showing that we're very far away from any types of specified goals.

MEMBER KRESS: That would be my guess, too.

MEMBER SIEBER: Ask me.

MEMBER KRESS: Well, that would have been my opinion. It's a subject we debate sometimes.

MR. WACHOWIAK: We do the analysis, but we would be very surprised if we found that that was limiting in our design.

MEMBER SIEBER: Do you have any estimate as to what the uncertainty is at this point in time in your analysis? I mean, you can get it to three decimals, but if your certainty is four orders of magnitude, you know.

MEMBER WALLIS: Well, this is a real mystery slide. I'd love you to explain this one.

MR. WACHOWIAK: Just to answer the uncertainty question, we have to look at uncertainty in several different ways, and so uncertainty itself, I'm not sure can be a number. There are things that we can do quantitative, you know, like Monte Carlo type uncertainty and get some information from that. We can do sensitivity analyses and we can get other information from that.

But I guess the question is if we say that core damage frequency is three times ten to the minus eight, are we really talking about a three times ten to the minus seven or three times ten to the minus four? Do we know where it falls in that range?

This would be a qualitative answer. I think that where we are right now is that we probably have an order of magnitude span on what we know. However, to address some of that though, some of our conservative or some of the numbers that we put into the analysis can compensate for some of that because we know we've been on the high side with some of the things like initiating event frequencies and things like that.

Also in features of the plant that we've chosen not to credit in the analysis at this point. So, yeah, there's some uncertainty, but it's not all uncertainty toward the high end.

CHAIRMAN APOSTOLAKIS: You say we're going to have a discussion of the core damage frequency later?

MR. WACHOWIAK: Yes.

CHAIRMAN APOSTOLAKIS: So let's go on to this.

MR. WACHOWIAK: So the intent of this slide is to kind of address some perceptions about what it is that the PRA that we have now is good for, and I'm trying to think of it now in the ASME capability category sort of thing.

Where we are now is that for some things in the PRA we could do anything, you know, anything up to the full capability Category 3. There are other things where we're not quite there. So it's really a continuum.

Probably if you went point by point in ASME, you'd find that we had a significant number of holes because we just don't know enough now.

CHAIRMAN APOSTOLAKIS: Can you remind us what capability means?

MR. WACHOWIAK: Capability category, well, that's the category where you can use it for, you know, the different type of changes, and that's the mindset that I had here when I was creating this.

CHAIRMAN APOSTOLAKIS: The dark blue means they're more capable?

MR. WACHOWIAK: Dark blue means --

CHAIRMAN APOSTOLAKIS: Higher capability.

MR. WACHOWIAK: It's probably more weighted toward --

CHAIRMAN APOSTOLAKIS: -- those where you are.

MR. WACHOWIAK: Where you are.

CHAIRMAN APOSTOLAKIS: The more they color them, that's where you are.

MR. WACHOWIAK: Yeah, and we see that as we move forward, we're going to be striving toward the best or toward the state of the art. We're probably not going to get there till well after operation. We're still going to have some places where we don't know everything, but the idea is that in the design phases, this is the right kind of mix for the DCD phase, and to look at things later, we want to be at the higher end.

CHAIRMAN APOSTOLAKIS: Is the length of the bars an indication of the uncertainties in the PRA?

MR. WACHOWIAK: No. It's an indication of what information is available to apply to the models that are said in the standards that we should be applying. So there are certain things that the standard says you have to do with your event tree analysis. Okay?

We've done all of those. I believe we're at the high end with that. There are other things that it says you need to do with operator actions. We're at the low end for that because we have just a bounding stream analysis.

MEMBER WALLIS: You're not going to change the structure of that significantly, but you will change the entries. You'll change the numbers.

MR. WACHOWIAK: And change the details.

MEMBER WALLIS: But I don't think you'll change the structure. The PRA we've seen is probably going to be about the same throughout. It's just that your numbers --

MR. WACHOWIAK: We may add some detail, and there's a potential to make some things clear in the future. We may expand the event trees to include more specific decision points, but the structure is the same.

MEMBER WALLIS: So it's still capable. It's capable now.

CHAIRMAN APOSTOLAKIS: I don't know that this kind of slide helps. May we move on? Let's just go on.

MR. WACHOWIAK: Okay.

CHAIRMAN APOSTOLAKIS: Let's go to something that we can really -- let's start seeing numbers.

MR. WACHOWIAK: We think we've got it.

CHAIRMAN APOSTOLAKIS: So where are we now? We are done with the overview?

MR. WACHOWIAK: Yes.

CHAIRMAN APOSTOLAKIS: Okay. then what's next, the prevention?

PARTICIPANT: Internal events.

CHAIRMAN APOSTOLAKIS: We were talking about the qualitative. Now we can move on to something quantitative.

MR. WACHOWIAK: Okay. The intro is the same.

MEMBER WALLIS: Key features, do we have this? Where are we? What is this? Prevention.

MR. WACHOWIAK: Internal events risk management.

MEMBER WALLIS: We don't have it.

MEMBER KRESS: Yes, you do.

MEMBER WALLIS: We have mitigation.

CHAIRMAN APOSTOLAKIS: I didn't have it. Now I have it. Do you have it?

MEMBER WALLIS: I haven't got it, by George.

MR. WACHOWIAK: It looks like this.

CHAIRMAN APOSTOLAKIS: So we're looking at ESBWR internal events risk management?

MR. WACHOWIAK: Yes.

CHAIRMAN APOSTOLAKIS: Okay.

MR. WACHOWIAK: The features of the plan are set out so that we have passive safety systems, active we call asset protection systems, and support system diversity. What we try to do for most types of systems is we have the passive function backed up by an active function, and then the way that the support systems are set up, they tend to support in a diverse way.

And this is the kind of target arrangement that we look at for each thing at a function by function level. Then we have functions that back up functions. We'll go specifically into some of those.

CHAIRMAN APOSTOLAKIS: Let's move on. Let's move on.

MR. WACHOWIAK: The systems that we have for the different functions. Passive system, you'll see that everything --

MS. CUBBAGE: Is lined up on the handout.

MR. WACHOWIAK: -- is lined up on the handout. I think we used a different font on this system.

So anyway, we have passive systems lined in all of the columns, sometimes multiple passive systems. We have active systems to back up all of these. Reactivity control, very important system for the plant. We have two essentially passive systems that address reactivity control.

We have two additional active systems that will provide backups to different aspects of those.

Pressure control, once again, passive. You can see SRV in two columns. There's a passive function on it. It lifts on spring pressure here.

It's inactive. You open the valves, and we'll talk about those.

Inventory control, which is a little bit different in this plan. We'll talk about that later, and high pressure. I mean, inventory control, low pressure. Inventory control low pressure. Gravity driven cooling system would be the passive system. Back that up with fuel and aux. pool cooling system in LPCI mode, and fire water injection.

CHAIRMAN APOSTOLAKIS: Why do you need the active backup systems? What's the whole idea there? Why not the passive only?

MEMBER SIEBER: You create an accident to get the --

MEMBER KRESS: Asset protection.

MEMBER SIEBER: -- stuff to work.

MEMBER ARMIJO: Well, you've got to operate the plant.

CHAIRMAN APOSTOLAKIS: I can ask you guys over at -- can we get GE's answer?

Why do we need active systems? The answer may be simple, but --

MR. WACHOWIAK: The answer is simple. It's recovery from the scenarios. The passive systems are extremely reliable, get you very quickly to a very safe state, but what it takes to recover from that state tends to be expensive.

CHAIRMAN APOSTOLAKIS: Why is that so? I mean, what do you need? Give me more detail.

MR. WACHOWIAK: For example, when you open the DPVs, you've basically created a steam line break inside the containment, and that affects different components that are inside the containment. That affects the EQ life of the cabling and solenoids and all of the electric components that you have inside the containment. It affects stress on things that you've evaluated to say that we can take so many of these transients.

So you may have to reanalyze or replace components that are inside the containment. If you get into a scenario where you actually have to use the passive systems, I think here you're creating a lot of stress on equipment that's inside the dry well when you use some of the passive systems.

So we have the active systems there that we can use to provide the same function and get us to a safe, stable state without causing an expensive recovery period.

CHAIRMAN APOSTOLAKIS: And then the opposite question is, you know, if that's the case, why don't you just use active systems? And is it such a big deal to have it declared as non-safety related? That's really one of the benefits here. The active systems are --

MEMBER SIEBER: Yes, yes, yes.

MR. WACHOWIAK: It is less expensive to buy and to maintain when they're not safety related.

CHAIRMAN APOSTOLAKIS: And the reliability of these systems expected by most reasonable people to be the same as that of safety related systems, right?

MR. WACHOWIAK: It would be similar to the types of things you'd see on oil platforms or in other industrial activities where high reliability is required.

So remember these active systems also -- most of these, main condenser, feedwater, if those systems aren't reliable, the plant doesn't make any money, and if they're not making any money, then what's the point of building it in the first place.

CHAIRMAN APOSTOLAKIS: Maybe it's obvious to people. You have the active systems because, you know, they don't create such a mess if you use them, right?

MEMBER SIEBER: Right.

CHAIRMAN APOSTOLAKIS: But you still have the passive systems.

MR. WACHOWIAK: Right.

CHAIRMAN APOSTOLAKIS: Which are the safety related systems.

MR. WACHOWIAK: That's correct.

CHAIRMAN APOSTOLAKIS: Overall you have a benefit, right? Compared to a system, a reaction that's only active?

MEMBER WALLIS: Well, you need the active so that you can talk about a CDF of ten to the minus eight.

CHAIRMAN APOSTOLAKIS: My question is what is the ultimate gain of using a combination of the two. What is it that you are gaining from that? Is it dollars? Is it perceptions?

MEMBER SIEBER: Yes, yes.

CHAIRMAN APOSTOLAKIS: Is it both?

MR. WACHOWIAK: Well, it is dollars because the passive systems are much simpler systems. Okay? So making a system safety related adds some exact cost associated with it. If it's a complicated system, the cost is more than if it's a simple system. If it's a simple system, it doesn't add as much cost.

So we like our safety systems to be the passive systems.

MEMBER SIEBER: The passive system is what gives you the low PRA numbers. If you didn't have those, you'd be --

CHAIRMAN APOSTOLAKIS: That's the whole point. They don't give any number.

MEMBER SIEBER: Yeah, they do.

CHAIRMAN APOSTOLAKIS: It's the active components that give you the numbers. Do you have any number anywhere that says this is the probability of failure of the passive, truly passive system? No. You've assuming --

MEMBER KRESS: That's called a focused PRA, which I think the staff is asking him to do.

CHAIRMAN APOSTOLAKIS: No, no.

MEMBER SHACK: Let GE answer the question.

CHAIRMAN APOSTOLAKIS: They assume that these active systems are not there. There is an explicit statement someplace that says we assume that the passive components do not fail, right?

In your passive system if you have a check valve that has to open, then you look at the failure rate of the check valve, but you never look at the failure of the tank or, you know, what are not coming down.

MEMBER SIEBER: Gravity is in the wrong

direction.

CHAIRMAN APOSTOLAKIS: Gravity may reverse itself, yes.

MEMBER SIEBER: There you go.

MR. WACHOWIAK: We didn't address the gravity reversing itself. What we did look at though is there are components in the systems that we call passive. Now, we have to remember here that passive is now a defined term. Passive -- a pipe is passive. We have pipe breaks in that analysis. We look at pipe breaks. That's a failure of a passive component.

MEMBER ARMIJO: As an initiator

MR. WACHOWIAK: As an initiator, but there are passive things that we call passive because they're operated only using essentially stored energy. It's not energy that we have to create.

So these DPVs that are fired using DC power from a batter, it's a split valve, DC power, that's been declared to be a passive component.

We have the failure rates of those types of passive components that need to change state in the PRA. That's where we get the numbers for the passive features.

MEMBER ARMIJO: What is an ARI?

MR. WACHOWIAK: Alternate rod insertion,

and I'll cover that on probably the next slide. I define all of these things.

MEMBER ARMIJO: Okay.

CHAIRMAN APOSTOLAKIS: So the combination of passive and safety related, non-safety related, overall results in benefits. It's cheaper; they're less expensive to design?

MR. WACHOWIAK: Less expensive design.

CHAIRMAN APOSTOLAKIS: What else?

MR. WACHOWIAK: By definition it's adding diversity. So it gets us to the lower -- somebody said it gets us to the lower CDF. It does because inherently it has to add diversity. If you have an active system and a passive system, they don't operate the same way. They don't have the same types of components.

MEMBER SIEBER: Fewer components to fail.

MR. WACHOWIAK: In many cases, there are fewer components to fail. Some active systems are fairly simple, but in general --

MEMBER ARMIJO: Passive systems are also easier to maintain than active systems.

MEMBER SIEBER: You don't have to do anything.

MEMBER ARMIJO: You don't have to do

anything.

MEMBER MAYARD: You will have some active systems that will be safety related, I would think.

MEMBER SIEBER: No.

MEMBER MAYARD: No?

PARTICIPANTS: No.

MEMBER MAYARD: Nothing? We'll see when you get to operation.

(Laughter.)

MR. HINDS: This is David Hinds.

Just to add just a couple of points just while we're on the topic, one thing to point out is that the column on the right, the active systems, they're not enough to license the plant by themselves. So there would be additional systems one way or another, the safety systems. Then it becomes a choice of are those safety systems active or are they passive.

So we would require those safety systems regardless. So, in essence, the column would not go away. It's just a matter of those systems, do we choose to design them as a passive system or as an active system. They would still be necessary.

And then some of the failure modes of the typical active systems that have a large number of pumps and motor operated valves and things of that nature, we went with the thought process of removing as many of those active failure prone components as possible, but the system needed to be there regardless of whether it was active or passive to perform that safety function.

So I don't think we're in a case of whether we could remove a large number of systems. It's just a matter of whether we choose to design them as active or passive.

MEMBER WALLIS: The passive aren't necessarily more reliable. They may not operate as designed. Your ability to predict how they operate may not be as reliable as it is for an active system.

MEMBER SIEBER: That's true.

MEMBER WALLIS: So it's not clear to me that passive is necessarily better.

MEMBER SIEBER: Well, you're reliant upon all of your thermal hydraulic analytical codes, and given what I know about that, I like --

MR. HINDS: We're reliant upon things such as static head of water in a tested integrated system as opposed to a conked (phonetic) head of water we felt would result in a more reliable configuration as well as there are economics involved as well.

MEMBER SIEBER: But the differential pressures that derive the flows are small in passive systems compared to, you know, a 5,000 or more starter pump.

MR. HINDS: And another note, too. Many of the components in the active category in this slide are typical power producing components that are necessary to generate electricity.

MEMBER WALLIS: But there are ways that passive systems can fail. I mean, you can have a pipe that's supposed to be full of water. For historical reasons it may have air in it.

MEMBER SIEBER: Or steam.

MEMBER WALLIS: And may not function the way it's supposed to function.

We should probably move on, but this whole idea that passive is necessarily more reliable I'm not sure is true.

MEMBER MAYARD: But those are applied to active components, too.

MEMBER WALLIS: That's right.

MEMBER MAYARD: If you're not meeting your tech specs with water where it's supposed to be --

MEMBER WALLIS: Have examples of that where the pipe that's supposed to be full of water is full of air. Then your pump can't suck.

MR. WACHOWIAK: So this is one of those examples where we really build on the safety analysis, the DBA analysis, because those types of questions, will it work, are answered in the DBA analysis for the most part.

Well, let's talk about the functions here. Reactivity control function. We start with RPS, reactor protective system. That's similar to most BWRs. It's a SCRAM function, failsafe I&N. So if it gets a signal it SCRAMs a plant. If it loses power --

MEMBER WALLIS: This is a case where you don't rely on gravity, right?

(Laughter.)

MEMBER WALLIS: You're pushing against gravity.

MR. WACHOWIAK: We're pushing the rods against gravity, but remember we are using a head of water to get them going, and then the flow through the core is actually what brings them all the way in. So it's against gravity, but it's still the passive direction when it goes that way.

Often a rod insertion, a question that was asked earlier, what does that do? It provides a backup to the RPS I&C function. So if for some reason that passive I&C function doesn't work --

MEMBER WALLIS: Now, do you credit that in your outsource analysis?

MR. WACHOWIAK: Yes.

MEMBER WALLIS: In your CDF?

MR. WACHOWIAK: Yes.

MEMBER WALLIS: So it's an active system, but it's credited --

MR. WACHOWIAK: In the PRA analysis, in everything except for the seismic margins analysis, we've credited all of these functions that I will be talking about.

CHAIRMAN APOSTOLAKIS: Is this a safety related system?

MR. WACHOWIAK: RPS is safety related. ARI is not safety related.

PARTICIPANT: Well it's active.

MEMBER WALLIS: Without BSE.

MEMBER BONACA: It's going to be what tier one says.

CHAIRMAN APOSTOLAKIS: RPS is not mired?

MEMBER BONACA: No, not yet.

MR. WACHOWIAK: ARI is not safety related. The fine motion control rod drive is also non-safety related. That's the typical way that we would move the control rods in this plant. It's different than what's in the BWR 2 through 6 out there now. It's an electrically driven screw arrangement to move the rods in and out of the core for normal power control.

MEMBER WALLIS: Excuse me. Now, this inserts different rods.

MR. WACHOWIAK: Same rods.

MEMBER WALLIS: Oh, the same rods.

MR. WACHOWIAK: All rods have this function.

MEMBER WALLIS: No extra rods. It's the same rod, different wave, but --

MR. WACHOWIAK: Right. So when we get a SCRAM signal, we also tell this fine motion control rod to start spinning its screws there. So if for some reason the stored energy control rod motion doesn't get all the rods, the ones that are back behind it, they take a little bit longer, but they also get driven into the core.

And then finally for the standby liquid control system, it's a sodium pentaborate solution just like in the existing plants. However, in our configuration, we have no pumps here. The solution is in a tank that's pressurized with nitrogen, and when you open the squib valve, the high pressure nitrogen drives the liquid into the core region, and I think maybe many of you have looked at that analysis.

MEMBER MAYARD: Is the ARI -- is that a fast insertion?

MR. WACHOWIAK: It makes the same thing happen as the SCRAM function, and so it's just barely, barely slower. The SCRAM function individually opens up all of the solenoid valves on each hydraulic control unit to vent each one. The ARI vents the header. So it, in effect, does the same thing, but it's not, in fact --

MEMBER SIEBER: It's not as close.

MR. WACHOWIAK: It seconds different.

MEMBER MAYARD: But you really have three systems putting the rods in the normal SCRAM. the ARI is the backup.

MR. WACHOWIAK: An ARI is the backup to the instrument and control portion. The RMCRD is the backup to the actual motion of the control rod. So it's really one backup system.

Once again, this configuration is extremely reliable, and when we look at our numbers, ATWS comes out to be less than one percent of total CDF with this configuration.

Pressure control function. First we have the main steam system. Obviously -- well, not obviously, in this plant it's capable of handling most of the transients, except for the ones where there's an isolation of that system for some other reason. It's capable of handling 100 percent of rated steam, 100 percent bypass capability on this plant. We're not limited by what we can put into the condenser.

The isolation condenser system now would be the next level of defense here. So this is one of these cases where the non-safety system is what we look at first. That's what we want to have. That's our preferred method of removing decay heat. If for some reason that won't work, that doesn't work or it becomes isolated, we move to the isolation condenser system or ICS, which provides decay heat removal. The key here is if this system goes into operation, we never lift any SRVs. So the challenge in the containment is eliminated essentially. It removes the heat. The isolation condenser pool is outside the containment.

And with this system we can sustain our safe shutdown condition for 72 hours with no human actions. With human action we can -- you know, as long as decay heat support it, we can stay there.

Finally, if we get to the point where we don't have either one of those, we do have safety relief valves, basically ASME type valves on the pressure vessel provides the backup, discharges into the suppression pool so that we minimize the impact on the containment itself. It really mostly discharges to the suppression pool because there are some that can go into the dry well, but those are sequenced on later.

Even in a transient where we did isolate the main steam and isolation condensers don't come on, there's several minutes before we pressurize the reactor enough to actually lift the SRVs.

MEMBER SIEBER: They're spring loaded safety valves?

MR. WACHOWIAK: Spring loaded.

MEMBER SIEBER: Not pilot operated.

MR. WACHOWIAK: They are pilot -- they're dual -- no? Alan has --

MR. BEARD: This is Alan Beard with GE.

They are spring loaded safeties when they are externally actuated relief valves, but only ten of the 18 actually have the external actuation for a relief function.

MEMBER SIEBER: Okay.

MR. BEARD: So eight are pure safeties,

and ten are a combination safety relief valve.

MEMBER SIEBER: Okay. How many valves does it take to comply with the code? One hundred percent flow, all 18 or some fraction?

MR. BEARD: A limiting situation is actually an ATWS event, and we need all 18 valves for that case. For the ASME over pressurization with SCRAM, it's significantly less than 18.

MEMBER SIEBER: Okay. Thanks.

MEMBER WALLIS: Now, there's no DPV on this slide?

MR. WACHOWIAK: No. This is the pressure control or over pressure protection on the vessel. The DPV is there for allowing the low pressure systems to actuate. This is just keeping the vessel intact following a scram or an ATWS.

So the DPVs don't play a role in what I'm calling pressure control. Pressure control is keeping from over stressing the vessel.

MEMBER WALLIS: With regard to filing?

MR. WACHOWIAK: As a matter of fact, because we have time in this plant from when you would reach that pressure, if it was not an ATWS, I'm not sure of the timing of the ATWS because I really haven't looked at that for actuating DPVs. We would have -- operators could in that several minute time frame actuate those.

We didn't take credit for any operator actions in that short of a time frame.

MEMBER WALLIS: Another way to depressurize.

MR. WACHOWIAK: It would be another way.

The result of this type of configuration in our analysis is that the vessel over pressurization comes out to be a negligible impact. We don't see any sequences or at least anything that significantly affects the core damage to get there, not in the limit of precision that we're looking at.

MEMBER WALLIS: There are sequences that you pursue though.

MR. WACHOWIAK: Yes.

MEMBER WALLIS: Where the vessel pops and it pops the containment.

MR. WACHOWIAK: Yes. We have those.

MEMBER WALLIS: Just the number associated with that is very small.

MR. WACHOWIAK: They just die out through the quantification and don't quite make it to the end.

The next thing is the inventory function at high pressure. This one is a little strange because of an isolation condenser system. We'll get to that in a second.

Feedwater system, once again, that's what we want to use if at all possible. It's available most of the time, a highly reliable system. It does require our preferred power system which would either be -- you know, it's what has typically been called a pass off-site power. We have some other capabilities in this plant, but for now we'll just call that the preferred power system there, not diesel generator backed up. It takes the grid type power.

Capable of handling any transient and small LOCAs. We can deal with those, and actually up to some fairly significant LOCAs if we can get the system back in line.

MEMBER SIEBER: Just keep pumping.

MR. WACHOWIAK: Just keep pumping until you run out of water basically.

MEMBER ARMIJO: How big a break would that be?

MR. WACHOWIAK: Essentially we could handle any break. The problem is the timing. When does the system isolate and when can you get it back in service, and I think in the different LOCA scenarios, I think we my have credited it in the medium LOCA, which is essentially a three inch line break.

The next backup is the isolation condenser system. We saw that in the pressure control. If these come into operation, it provides the pressure control, but because it's closed loop cooling, it condenses all of the reactor steam. We don't need any kind of makeup.

Once again, that was key for not lifting the SRVs or not losing inventory. So as long as we're not losing inventory, this can keep us in that state for at least 72 hours, potentially forever.

Finally, the other backup that we have that actually starts, comes into service at about the same time as the isolation condenser system, is the control rod drive. Here our control rod drive pumps are not your father's control rod drive pumps. They're 500 GPM each. We have two of them, fairly substantial. Provides backup high pressure injection function that could be used independently of these.

This is backed by our non-safety diesel generators. So it could be off-site power or on-site power.

Handling any transient. When I say here "most LOCAs," the flow rates were designed with the small LOCA in mind, but what we see is if it's a steam LOCA also because of where the water level comes out, this 1,000 GPM that we can put in with these two pumps quickly balances decay heat and we can keep the core covered with these systems even if the plant depressurizes and there's a bigger LOCA.

This combination here, once again, these are all systems that are in the analysis. They help maintain the low CDF, and when we see later in the results one of the reasons why this doesn't make it negligible with this configuration is what happens between the 24 and 72 hours and what has to happen there.

We're finding the PRA to address that, but we haven't quite addressed it yet.

And we've got the low pressure function.

We didn't credit in the PRA the condensate function. A lot of existing plants look at condensate for providing low pressure injection. When we looked at it, we saw that there were so many commonalities with the feedwater system that we just previously talked about, and the feedwater system was already credited in those analyses. We didn't see a lot of extra benefit to adding the condensate system.

So it's there. It's just not on my list.

We thought it was fairly dependent and it wouldn't make much difference in the resolves. So then we get to low pressure then. We've got the gravity driven cooling system.

Here's our passive operation, the tanks that you saw inside the vessel there in our sketch on the front of each page or each presentation. It's inside the containment. All water that we need is already there inside the containment. It doesn't need to be augmented in any scenario where the containment remains intact.

Back up to that would be the fuel auxiliary pool cooling system in LPCI mode. LPCI mode of operation can transfer suppression pool water into the vessel just like existing LPCIs do.

Power, once again, on this one is backed by the non-safety diesel generators. We have a third method of getting water into the plant through our diesel driven fire pump. We have provided a hard connection to put that fire water into the vessel if needed.

We don't need any AC power to run this. It's independent.

So again, this combination along with the high pressure helps maintain the low CDF.

Talking about the depressurization function, depressurization valves, we call them the DPVs. Passive operation, once again, that means it's stored energy. It's a squib valve. It has got a charge on it. You applied power from the batteries however it gets there, but power from the batteries that fires these.

They open. It discharges directly into the dry well. A fairly large opening when they all go off.

It provides complete depressurization, and that's the key for the GDCS operation, is that you get the dry well and the reactor at the same pressure so that the head of water in the GDCS tank can allow the system to drain.

We do have --

MEMBER SIEBER: How long does it take to get that equalized pressure? It's a matter of seconds, right?

MR. WACHOWIAK: Yeah, it's not very long. Do you remember, Alan?

MEMBER SIEBER: Ten to 30 seconds?

MR. WACHOWIAK: It's in the DCD. I can look it up.

MR. BEARD: Yes, this is Alan Beard again.

Actually the sequence is the initial depressurization is through the safety relief valves, the relief function.

MEMBER SIEBER: Right.

MR. BEARD: We blow it down to about 20 pounds gauge before we'll open up the DPVs to lessen the transient on the blow-down in the dry well. So overall to get down to that zero differential pressure, it's on the order of 30 seconds.

MEMBER SIEBER: That's what I figured. Thanks.

MR. BEARD: That's one of these things where in the design basis analysis, we look at the sequence a little bit differently. We looked at the DPVs independent from the SRVs when in actuality the real sequence is the SRVs open first, and then the DPVs open second, and what we tried to do in the PRA is that we don't want to specifically just say you have to have both. We look at what kind of redundancy we actually have here.

For GDCS operation, we need the DPVs. For some of the other things, LPCI or fire water, the SRVs by themselves are sufficient to operate those systems.

MEMBER MAYARD: And these are considered passive valves, DPVs?

MR. WACHOWIAK: The DPVs are considered passive, yes. Squib valves that are powered by our batteries, all stored energy devices.

MEMBER ARMIJO: What actuates those things? What causes the battery to send the signal to this squib valve? How do they work?

MR. WACHOWIAK: Essentially what happens is we've got our level control system, and I'll just go through the simple case on level control. As in the existing BWRs, there's a Level 1, which will be the ECCS actuation level. That signal then is going through the different systems and sends a signal to open the SRVs first and the DPVs and then the GDCS valves. It goes through that system.

The I&C is powered by the batteries, and the power that goes to the valves also comes from the batteries. So it's a digital I&C system that's doing that.

MEMBER ARMIJO: Okay. Thanks.

MR. WACHOWIAK: Okay. So again, this is a very reliable configuration the way it is. The high pressure sequences amount to less than two percent of our CDF. So we see if we have a low core damage frequency. Everything tends to be in the low pressure range.

We talk about the decay heat removal function here. This really only applies to the Level 2 analysis, but we'll look at it here in the list of functions.

The main condenser is available. That's where we want the heat to go. That's the easiest way to transfer it to the ultimate heat sink. If we get into one of these other scenarios, once again, ICS will do it by itself, and you start thinking that ICS is a pretty important system in this plant. It provides a lot of functionality, a lot of protection in many things.

We've got the passive containment cooling system which, if there is steam in the dry well, it will perform its function. It won't perform its function if you don't have steam and the dry well has got to condense the steam.

This one, again, doesn't need any support systems at all for 24 hours. If you open the DPVs, the passive containment cooling system starts working. We say for 24 hours because at somewhere after 24 hours the design requirement in that 24 hours --

MEMBER WALLIS: This is on the noted containment?

MR. WACHOWIAK: Yes, it is.

MEMBER WALLIS: And so you've got all of these noncondensables that have to go somewhere.

MR. WACHOWIAK: That's correct.

MEMBER WALLIS: So in order to keep track of them in evaluating your effectiveness in condensation, I guess we're going to get into that.

MR. WACHOWIAK: We'll get into that in the presentation this afternoon. I talked specifically about how the noncondensables are dealt with in the PCCS, but in general, if we start out with a LOCA it's fairly simple.

Pressure suppression containment works like GE pressure suppression containments have in the past. The steam drives the noncondensables through the vents in the suppression pool and they're trapped in the suppression pool.

But the way the PCCS works, it also provides a mechanism for driving the noncondensables in the suppression pool. So in the long run, all of the nitrogen is in the suppression pool, and the PCCS is a self-regulating device then that can operate indefinitely as long as you have water.

And at this 24 hour point or analytically we show later than 24 hours, but at that point you need to get more water. We have an automatic means of opening some valves to automatically bring -- seeing gravity driven more water there, but there are other backups to that.

MEMBER SIEBER: As far as condensation is concerned, it doesn't make any difference whether it contains it or not.

MR. WACHOWIAK: That's correct.

MEMBER SIEBER: If there's not noncondensables in there, then it's the same inventory.

MR. WACHOWIAK: For a Level 1 analysis, whether it's inert or not doesn't make any difference.

MEMBER SIEBER: That's right.

MR. WACHOWIAK: Another backup system to all of this. As long as you have enough inventory in the vessel, you've got the reactor water clean-up system. It can operate in a shutdown cooling mode. So just like RHR works now, our reactor water clean-up has that same RHR function. It can be placed into operation back by the non-safety diesels. It does require service water and things like that to operate.

MEMBER SIEBER: It is basically a high pressure system.

MR. WACHOWIAK: Yeah, it operates at high pressure in reactor water clean-up mode.

MEMBER SIEBER: Right.

MR. WACHOWIAK: And then you can switch it into a shutdown cooling mode that can go essentially from rated pressure all the way down to cold shutdown.

MEMBER ARMIJO: But can that by itself provide all of the decay heat removal you need or just a fraction of it?

MR. WACHOWIAK: Yeah, go ahead.

MR. BEARD: Yeah, Alan Beard with GE again.

It is a full pressure rated system. The heat removal capacity will not match the decay heat curve for about the first hour. We do need some --

MEMBER ARMIJO: Something else.

MR. BEARD -- the first hour of heat. In about the first hour though we come into the decay heat curve, and the reactor water clean-up system by itself will be able to locate the decay heat.

MEMBER ARMIJO: Thank you.

MR. WACHOWIAK: The one point I want to bring out here is if we're looking at the challenge to keeping the vessel or the core covered, if we have the injection functions that we've talked about earlier, we don't need the containment heat removal function for more than 24 hours. We will talk about that a little bit more in the Level 2 analysis.

But in the first day if we don't activate any of these things, we still don't get to a point where our active systems are being challenged or where the -- it's not the active system. It's where the level in the vessel is being challenged.

Someone asked a little bit before about how some of these diverse control systems were. This is our schematic from Chapter 7 in the DCD. Essentially how we get the actuation of the DCD and the GDCS valid.

MEMBER WALLIS: This is all illegible and proprietary. None of the printing came out in this.

MEMBER SIEBER: It works for me.

MEMBER DENNING: Yeah, it's out of focus, even on the printed page.

MEMBER SIEBER: Don't worry about it.

MR. WACHOWIAK: It's not fuzzed up intentionally. It's a process where you go from a drawing to a PDF back to a drawing to a printing.

MEMBER SIEBER: It works for me.

MEMBER DENNING: This is PRA.

MR. WACHOWIAK: But you'll find this drawing in the DCD, Chapter 7.

MEMBER SIEBER: There you go.

MR. WACHOWIAK: It's in there.

MEMBER SIEBER: As a PDF.

MR. WACHOWIAK: Yeah, meeting all of the pixel requirements that were done.

Essentially we've got two -- for each valve, whether it's a DPV or whether it's a GDCS valve. We've got one valve. On that valve there are two drivers or two charges for the squib. So the squib needs to fire to open the valve. We've got two of them on there. Each one gets a signal from a different train to the system.

Look at the bottom one here. It's a simple one. This is the safety related I&C system. Its signals come in from all four divisions. It votes on whether or not we've actually received the signal that we expected to see.

It sends a signal to -- independently sends a signal to two different load drivers, which allow power to go to that squib and actuate it.

We've duplicated that from a different division on here, but we've also provided a parallel signal in from what we call the diverse protection system to perform the same function.

Now, what's the diverse protection system? This is a separate instrument and control system in the plant. We call it diverse. So we're pretty much saying that it's diverse in manufacturer, hardware, software, that looks at the different ECCS functions and provides a backup signal, if you will, to those different functions.

So if for some reason we have got some failure in the safety system, we have a backup system for that. It can fire one of these. The part that's common here is the DC power comes from the station batteries, and we didn't duplicate the diverse station battery.

MEMBER ARMIJO: If sensors failed, would this system operate? The sensors that say, okay, something is wrong; level is wrong. If those sensors failed?

MR. WACHOWIAK: We would have to fail -- with this configuration here, we would have to fail at least four sensors, two in each system, where two in each system. So two in the safety related system, two in the non-safety system would all have to fail. So if you have any two that work in the safety system and any two that work in the non-safety system, this will actuate. So you would have to fail three. I'm sorry. I got my successive failure back.

So any two in the safety system that work or any two in the diverse system that work will get this actuation.

MEMBER ARMIJO: Okay. Thanks.

CHAIRMAN APOSTOLAKIS: Rick, it seems to me this is a natural place to break.

MR. WACHOWIAK: Okay.

CHAIRMAN APOSTOLAKIS: The next one is an event tree. Question?

MEMBER BONACA: Just a question generally to do with the reactor safety systems which most of them, they're not safety related.

MR. WACHOWIAK: That's correct.

MEMBER BONACA: Okay. How do you envision that that will affect testing? And how do you account for, for example, if you have less test requirements since you impose on the systems because now you have the reliance on the passive systems as a major blackout.

You know, I can see advantages there for the operator. How do you account for those? And do you foresee it will be different with panel availability of the system because they're not being tested as frequently?

MR. WACHOWIAK: One thing about our active systems is that they're not just there to sit and do nothing while we're waiting for an accident or transient to happen. All of those active systems, except the SRVs, really have some function to play in the operation of the plant.

FAPCS is sued for water transfer and pool cooling and pool clean-up, things like that. So all of these active systems that we have need to be operating, most of them continuously, some of them very periodically in order to do your role operation of the plant.

So the list of things that are in standby for the active to perform these active portions of the function is a very small list.

MEMBER BONACA: Very small list. Okay. Thank you.

CHAIRMAN APOSTOLAKIS: Okay. We'll break until 10:27.

(Whereupon, the foregoing matter went off the record at 10:13 a.m. and went back on the record at 10:31 a.m.)

CHAIRMAN APOSTOLAKIS: So we are back in session please.

MR. WACHOWIAK: Okay. Now that we're back and I'm on, I wanted to go through a couple of the event trees here. With the time frame we have, we couldn't necessarily go through all of them. I want to just talk about a couple of representative event trees.

The first one, I think, is the general transient. This is the way we'd like the things to go, well, at least the top part.

You have some sort of transient with successful RPS. Bypass valve opens to the main steam line. We have feedwater available. We're okay. That's not so much different than what you see in any BWR.

So as we go through the different systems here, if for some reason we don't have the bypass or we don't have the feedwater system, what we end up with is in --

MEMBER WALLIS: When I was reading this, there's all of the acronyms and things, some of which didn't seem to even be defined anywhere. This diagram is full of these PRFLs and things. You have to figure out what it means.

I have great difficulty even in the list of acronyms finding some of these.

MR. WACHOWIAK: I'm sorry. In the presentation itself or you are looking in --

MEMBER WALLIS: In the document, in the

document.

MEMBER SIEBER: Proprietary.

MR. WACHOWIAK: Yeah, that's a --

MEMBER WALLIS: Maybe they're hidden in the text somewhere or something, but anyway it's just a comment on this.

MR. WACHOWIAK: Yeah, the headings for these things should be in Chapter 3 of the PRA, and I thought we had those.

MEMBER WALLIS: Maybe they're in there somewhere, but they're not gathered together so that you can find --

CHAIRMAN APOSTOLAKIS: Also in the printed version and the electronic version in some of these event trees you just can't read your headings, especially for the loss of power, which contains a sequence that is a dominant sequence, number 44. It's really impossible to read the headings, and I notice you don't have a tree here.

MR. WACHOWIAK: Not on this presentation, and I do have it on my computer. We can talk about that one, too, if you wanted to. We'll figure out how to do that in the document. We're somewhat bound up by our software and the ability to get the nice pictures out of the software and into a document. We can make it into a stand alone drawing for you and send it as a stand alone printed drawing, but to send it electronically, it's in the format of the software, and I'm not sure that that's --

CHAIRMAN APOSTOLAKIS: Do you have a bigger figure, you know? You know, print it and send it to Eric.

MR. WACHOWIAK: We can send hard copies of the event tree, and we can send all of those. We could seen, you know, big, 11 by 17 hard copies.

MEMBER SIEBER: That would be useful.

MR. WACHOWIAK: Once again, it loses a little bit when you convert it into the PDF, but we'll see what we can do. If it's possible to get that 11 by 17 scanned into a PDF that's got a high resolution, we can do that.

But when we go from the software and print to the PDF, it loses it.

CHAIRMAN APOSTOLAKIS: You have to go to the microphone and identify yourself, please, with sufficient clarity and volume.

MR. BHATT: My name is Sid Bhatt, and I'm from GE.

Regarding this form place, you have been using only the 11 by eight -- 11 by 17, and it's easier to read. I agree with you, and we can provide you for what Rick has been saying in Section 3. Basically that's where all of those trees are defined, and we can give you that set so that you can see T-44 and other things too. But that is probably the best way to give it to you, would be a hard copy if it's okay.

CHAIRMAN APOSTOLAKIS: Yes, sure. We'll take that.

MR. WACHOWIAK: Okay, and we'll do that.

The question about all the different headings here being defined somewhere. I know we discussed them in Chapter 3, in the original and in Rev. 1, Rev. 0 and Rev. 1, but you're right that there isn't a "here's a list where all of them are."

CHAIRMAN APOSTOLAKIS: Part of the problem is that the actual headings of these three, for example, where it says "I," you're not going to find an I because you will find IC in the list of acronyms.

You see you have an I there on the fourth column? It's really IC. So if you go through the list of acronyms looking for I, you're not going to find it. You're going to find the IC.

And for some reason you're using U1CF when it's high pressure injection, right? These are the computer --

MR. WACHOWIAK: It's one version of high pressure injection.

CHAIRMAN APOSTOLAKIS: So these I doubt you will find in the list of acronyms because they are just computer acronyms used in the calculations.

MR. WACHOWIAK: Basic event --

CHAIRMAN APOSTOLAKIS: The actual systems are below.

MR. WACHOWIAK: Right.

CHAIRMAN APOSTOLAKIS: Well, you know, the completely scrutable PRA will be produced when there is a really complete PRA, which means never.

It's okay. I mean, we don't want you to be shocked.

MR. WACHOWIAK: I'm just trying to remember where I was.

(Laughter.)

CHAIRMAN APOSTOLAKIS: These things happen, but it was interesting that especially that transient for the loss of feedwater and loss of preferred power, which were really of interest, there is no way you can read the headings. It's not a matter of finding any of the acronyms. You just can't read them at all.

MR. WACHOWIAK: You can't read it when it got into the file. We'll get that fixed. It may take a separate document to do that. Getting it into the one concise document is difficult.

CHAIRMAN APOSTOLAKIS: Well, today you are giving us an overview of the whole thing.

MR. WACHOWIAK: Yes.

CHAIRMAN APOSTOLAKIS: And then I hope at the end of the meeting or maybe at the end of the day and at the end of tomorrow we can identify some topics on which we would like a more detailed presentation some time in the future.

MEMBER WALLIS: Well, apparently the Spell Checker doesn't work on the PRA either because there's typos all over the place.

MR. WACHOWIAK: In these?

MEMBER WALLIS: "Inyection" and "suppresion" and "equilisium." I mean three typos in one chart.

CHAIRMAN APOSTOLAKIS: I can assure you PRA has nothing to do with it.

MEMBER SIEBER: Hey, the PRA folks are doing the best they can.

CHAIRMAN APOSTOLAKIS: Why don't you go?

MR. WACHOWIAK: Okay. If we move on then, we don't have the regular power conversion system, which would be the main steam along with feedwater. We move and we check the isolation condenser. Three of four goes into operation; we're okay.

I think I heard a question somewhere in the audience about passive things that need some kind of a signal to actuate. The isolation condenser itself is one of those systems where if we lose power or lose the signal, the I&C signal goes into operation on its own. So it would be activated, and so long as we keep water in the upper pools, it will take us out as long as we need.

We don't have the isolation condensers. We asked do we over pressurize the vessel, and here you notice that we've used one of the 18 SRVs. The likely case in the loss of ICs is that we would have some IC capability. We just wouldn't have enough to prevent the actuation of the SRVs.

After we get into more detail, we can see what value should be put there and what we actually need to prevent failure of the vessel versus just in the ASME's range, the stress on the vessel.

CHAIRMAN APOSTOLAKIS: So these, the second here out of the success criteria --

MR. WACHOWIAK: It relates to success

criteria.

CHAIRMAN APOSTOLAKIS: So these were presumably derived by doing the appropriate thermal hydraulic calculations.

MR. WACHOWIAK: Yes.

CHAIRMAN APOSTOLAKIS: And somebody is checking those, the status of it, I suppose.

MR. WACHOWIAK: We're checking those, yes.

The next one we get to if we do successfully keep the --

MEMBER WALLIS: Well, what's the probability of 17 of these things failing?

CHAIRMAN APOSTOLAKIS: Very low.

MR. WACHOWIAK: Very low, and it's the same probability as 16 failing and 15 failing and 14 failing. So once again, we didn't really get into revision of that number so much since you don't have the ability to resolve it down to the difference between 11 failing and 18 failing. It's the same thing.

MEMBER SHACK: What calculations do you use for the PRA, what thermal hydraulic code?

MR. WACHOWIAK: We can talk about that a little bit later, but it's a combination of things. For some things where it's obvious, where we're looking at things like for that one feedwater pump can provide injection since one feedwater pump is capable of 45, 50 percent of rated flow, certainly it can take decay heat. We have a hand calculation for that.

For other things where we have our design basis analysis, and this particular case here, three or four isolation condensers, we've used Track G in the design basis calculation to show that that's success, and we've just adopted that here in the PRA.

Other things that are a little more complicated that involve multiple failures. We couldn't just lift directly from the safety analysis, and we've done calculations with MAAP 4 on those, and we're in the process of discussing with the staff how to resolve any sort of uncertainties or other issues associated with using that code.

MEMBER WALLIS: Well, these are very simplistic. On the idea that isolation can then -- it either works or it doesn't, it's just not quite like a pump. I mean, it could get blanketed with no condensables and work to some extent. There's a whole lot of these things which can partially work.

And the FEPRA says it's there or it isn't there, which is very unrealistic for some of these systems.

MR. WACHOWIAK: Yeah, we didn't really address partial failures of the systems, but if you do go into the default tree for the isolation condenser, the purge valves for the noncondensables are in there to the extent that we would need those.

So we didn't really look at saying, well, we have two and a third equivalent heat exchangers. We've just said does it function the way it's supposed to, just like you would in the active PRA.

MEMBER WALLIS: And the other thing is if you put the uncertainties in the thermal hydraulics into this, then you could be moving from one branch to another because of, you know, being on the tail end of some probabilistic distribution of the heat transfer coefficient or something, and that's not in here either.

MR. WACHOWIAK: That's not in here in that exact what. What we've done, and we're still addressing this, is that when we set the success criteria or the threshold for saying success versus failure, when we use MAAP what we did was we didn't look at actual heat-up of the clad and the onset or the failure of the clad. What we really looked more at was did we uncover the core.

So where we set our threshold for saying it's success or not should address things like those types of thermal hydraulic uncertainties. The question that we're dealing with now is is our method for calculating when we get to the top of the core -- is that an adequate way of doing it?

I think that at least at the preliminary stage we have I can't call it agreement yet, but we have a conceptual agreement that those thermal hydraulic margins could be handled by setting the threshold at the top of fuel rather than doing the detailed calculations.

So, again, I would think that this is something that's appropriate at this DCD phase to use that type of a conservative analysis to address success criteria and maybe do something more detailed as we move forward. But I think there's other uncertainties that would be bigger than that particular one when we justify the margin.

We're working on that.

CHAIRMAN APOSTOLAKIS: The way I understand it, today's presentation will not get into methods for doing things, to quantifying. You're just presenting results and --

MR. WACHOWIAK: Okay.

CHAIRMAN APOSTOLAKIS: -- how it was done.

MEMBER WALLIS: Can't we ask that? Can't we ask if we wish how did you get something?

MR. WACHOWIAK: You can ask.

CHAIRMAN APOSTOLAKIS: You can ask.

MEMBER WALLIS: But they're not going to reply?

CHAIRMAN APOSTOLAKIS: What I think we should do as we go on, we should identify -- let's not wait until the end of the day -- that we would like to revisit in more detail at a future time, and here you have -- I mean, when you have 18 lines, then the issue of common cause failures, I guess, becomes important, and at some point in the future we'd like to discuss this with you, how you did it.

You say in the document you used the alpha factor method, and I looked at the table there and some of the numbers appear to be low to me, but there may be a good reason for that. So this is one items we have to do in the future.

MR. WACHOWIAK: Okay.

CHAIRMAN APOSTOLAKIS: Get more into the methods for doing things because you have extremely done that in so many places that it drives them out of style. Also the failure of data, that you use the uncertainty analysis that you did.

I guess this meeting is not really methods oriented. It's more this is what we did; this is the results, and in the future we will have done this with some of the methods.

MR. WACHOWIAK: Okay.

CHAIRMAN APOSTOLAKIS: Is that agreeable? Great. Thank you.

MR. WACHOWIAK: And we'll be happy to revisit those.

CHAIRMAN APOSTOLAKIS: Great.

MR. WACHOWIAK: Or we can arrange it.

Gather my thoughts again. I'll move into the high pressure injection sort of range that is again here, one of two CRD or one of two -- these are feedwater trains, I guess, rather than -- it would be one of those typos that you are talking about. It could be one of four feedwater pumps.

The reason we ask that again here is because this could have failed because of the steam bath and not just the feedwater. We pick up that dependence again by looking at feedwater or control rod drive here.

Once again, the single control rod, if we get through this path, the single control rod drive pump is sufficient to keep the core covered. Balances decay head before we get to the top of fuel.

If we need to go into the low pressure, we look at a combination of SRVs and the active system to provide that or, conversely, the DPVs and our passive systems to provide the injection. The combination of things in the passive systems is addressing a little more than the short-term cooling, is set up to allow us to address a long-term cooling there. We do think that there may be some conservatism in the way that we have addressed this, at least looking at the equalizing lines.

Finally, when addressing the low pressure injection systems, if the DPVs have actuated, have actually actuated, we put this in here again because the training and dependence for the operators is different between these two. So we asked for that, again, in that scenario, to pick up that dependence.

In the end, the way we've drawn these trees, they look fairly simple. The underlying fault trees that go into these are a little more complex that way. It's a tradeoff of how people like to do these analyses. Some like to see more detail in default trees. Some like to see more detail in the event trees. For illustrative purposes, I think it's easier to show in the event trees, but again, it's a choice for how we address these things.

I just mention a couple of other things. The question came up about what happens if we stress the vessel, if we take that as a transfer into one of our other trees and we analyze that as an initiator going into the other tree. Similarly, we do the same thing with ATWS, where we have a separate event tree that discusses the sequence of events that would happen in an ATWS.

MEMBER WALLIS: Now, when you use this for design --

MR. WACHOWIAK: Okay.

MEMBER WALLIS: -- do you say that you want something like the same probability in each one of these branches or do you say we want a low probability at the beginning so that we don't get into some of these sequences later on? How do you decide you're going to have a certain number of DPVs, for example?

Presumably it's based upon some kind of balancing of the various contributions to the PRA. So how do you do that in the design? How do you use something like this for design?

MR. WACHOWIAK: The way that we did that was remember the columns from earlier this morning?

MEMBER WALLIS: But what about quantity. You're going to say we want a certain probability at this price, don't you? Therefore, we're going to have a certain number DPVs. Is that the sort of thing you do?

MR. WACHOWIAK: Yes.

CHAIRMAN APOSTOLAKIS: In other words, if we want higher reliability on the left --

MR. WACHOWIAK: Right, more reliability on the left.

MR. WACHOWIAK: What we really want to do is we want to minimize these high pressure scenarios.

MEMBER WALLIS: But you can do that by different parts of the --

MR. WACHOWIAK: You can do it with different parts.

MR. WACHOWIAK: Right, right.

MR. WACHOWIAK: In the first phase where we looked conceptually at what we're going to do when we had discussions, based on experience from previous plants, the question on SRVs and it wouldn't be experience with DPVs, but experience with things like SRVs, the question was: what type of redundancy would we like to see in this system?

And I said, well, you know, based on what

I've seen before, I think if we had at least an additional three, that should give us a low enough probability here that would drive the numbers toward the direction we want to have in the low pressure core damage so that the bulk of the core damage frequency would be in the lower pressure scenario.

So that was what I call a qualitative judgment on that. So we do that, put that into the conceptual design. Then we take the conceptual design and put it into actual fault trees and use it that way. So we confirm --

MEMBER WALLIS: But how did you balance things? I mean, you can change around tremendously the importance of different steps in this process, and they're in default tree. So 21 SRVs or ten instead of 18 or I mean, you can change the importance of certain of these branches by design, right?

MR. WACHOWIAK: That's right.

MEMBER WALLIS: How do you decide what to do?

MR. WACHOWIAK: I think the key here is that you can't only use this to optimize that because there --

MEMBER WALLIS: So you don't have a system, right? You don't have a system. You don't have an answer that's --

MR. WACHOWIAK: We didn't do it that way is what I'm saying.

MEMBER WALLIS: You don't have an explicit --

MR. WACHOWIAK: We didn't say --

MEMBER WALLIS: -- logical --

MR. WACHOWIAK: -- you have to have a number that's this good here.

CHAIRMAN APOSTOLAKIS: And from the PRA perspective, whether you have a ten or 16 or 14 lines is irrelevant. I mean, PRA cannot distinguish among these. I mean, you bring in the common cause failures after three or four or five at the most redundant lines. Then the number is the same. So you have to use some other argument why you want to go to 17.

MR. WACHOWIAK: That's right.

CHAIRMAN APOSTOLAKIS: And that's what I think you said, you know, that this is not the only way to do this. I mean, actually the issue of common cause failures and their use in design is a real one because the methods have been used, you know, for existing plants as an assessment tool, and so on, and the numbers that you're getting are not very sensitive to certain things a designer can do, like having extra lines or increasing the separation. I mean, it's all a matter of judgment.

MEMBER BONACA: I say it's look at what -- you know, is that you really more than -- I mean, the PRA helped you, but you really used a lot of the BWR experience.

CHAIRMAN APOSTOLAKIS: Exactly.

MEMBER BONACA: And the PWR as a basis. I mean, that's where you start from, and I think that's an advantage. You have that advantage. You should use it.

MR. WACHOWIAK: We want to get as close as possible to what the design is going to look like before we even have to go into one of these detailed models.

MEMBER WALLIS: But there's no concept of what sort of the optimum design strategy would be or anything like that? It's just what you happen to have? You draw a figure and you take what you've got and you say, "Well, that looks okay."

MR. WACHOWIAK: Well, no. One of the things that we looked at actually got on this particular figure, but it would have been on the reactor water clean-up line break outside the containment, and we went through. We had our conceptual design of how we wanted that to look. We modeled what was there, and when we looked we saw, you know, this break outside the containment fraction, the core damage frequency is higher than we wanted it to be. We want it to be negligible. We don't want a break outside the containment leading to core damage in a bypass. What can we do so that this is no longer a non-negligible sequence?

So we went back to the designers and said, "What can you do to increase the reliability of the isolation of that system?"

And we added an extra automatic isolation valve or isolation itself. It's not really just one valve. We added an extra automatic isolation from a diverse system into that line which now when we put that back into the model, lo and behold, the containment bypass sequences are now negligible.

So that's really the process we went. We didn't try to say we have a target value for each of these branches. We do know that in general we want the bypass sequences to be negligible. We want the high pressure sequences to be low, and we want the overall core damage frequency to be low in terms of what people are used to seeing.

CHAIRMAN APOSTOLAKIS: I can see the PRA

being careful because you move down to lower levels, the system and component. Then the value of the PRA begins to diminish because the models are not so sensitive by that.

MR. WACHOWIAK: We can find other things. We found places where we identified manual valves that are used for maintenance that would need to be instrumented and alarmed because if they are left in a misposition condition after maintenance, it tended to drive up the reliability of some of these or under liability of some of these systems.

So we go back to the design and say, you know, we understand you're going to have component checklists for these things, but let's add something else on top of that. We want to make sure that these aren't left in a state where they may not be able to perform their function.

So we use it that way rather than trying to set a target reliability for each step along the way. Once again, optimizing the entire plant that might get us into a -- if we tried to hit targets for every individual piece rather than looking at the end, we would get into a problem that might be hyper over constrained rather than one that's just over constrained now.

MEMBER ARMIJO: Rich, but what is the requirement for 18 SRVs? You've done this analysis --

MR. WACHOWIAK: ATWS.

MEMBER ARMIJO: ATWS. Okay. For that how many do you need?

MR. WACHOWIAK: Eighteen.

MEMBER ARMIJO: Eighteen.

MR. WACHOWIAK: To meet the ASME code for ATWS analysis, you need to have 18. So that drives that, and the PRA didn't say you need more than 18.

MEMBER WALLIS: So 18 barely meets the ASME?

MR. WACHOWIAK: Well, it meets it. I wouldn't say "barely meets it." It meets it.

MEMBER WALLIS: But you said you had to have 18 to meet the -- does that mean if you had 17 you wouldn't meet it?

MEMBER SHACK: You wouldn't meet the code.

MR. WACHOWIAK: You couldn't meet the code.

MEMBER WALLIS: You wouldn't meet the code. Okay.

MR. WACHOWIAK: In the PRA we ran a 100 percent ATWS case, and looked at things like when feedwater ramping down and reactivity control as the level came down, and determined that we would not get the vessel to a place where it would fail, and I don't remember what the specific number that we used was for that, with nine SRVs open.

So we looked at the expected scenario for an ATWS and looked at how many SRVs did we have to have open before we would actually get to the point where we were failing the vessel, not just exceeding code, but failing the vessel.

CHAIRMAN APOSTOLAKIS: Coming back to the issue of having more reliable systems on the left, aren't these the systems that really are involved in the design basis accidents so that the conservative analyses there indirectly lead you to very reliable systems?

MR. WACHOWIAK: Certainly the design basis analysis uses the reactor protection system.

CHAIRMAN APOSTOLAKIS: Right.

MR. WACHOWIAK: The design basis analysis uses the isolation --

CHAIRMAN APOSTOLAKIS: Right.

MR. WACHOWIAK: It uses these SRVs. It uses the DPV and GDCS systems. The FAPCS is probably not included in the design basis, and the fire water injection is not included in the design basis.

As CRD is an injection system for some of the sequences, it isn't analyzed or it isn't used in the design basis, but once again, we set the criteria based on an ALWR URD requirement that we do have an active system to mitigate small LOCAs.

CHAIRMAN APOSTOLAKIS: Okay.

MR. WACHOWIAK: Okay. To go to just another example here, the feedwater line break. The feedwater line break is what we call large steam LOCA. Steam LOCAs depressurize the vessel on their own. So once again -- and it's in the dry well. Just showing we don't need to ask things about the DPDs in these scenarios. We can go directly to the low pressure systems.

MEMBER WALLIS: This is a large LOCA and a feed --

MR. WACHOWIAK: Feedwater line break.

MEMBER WALLIS: Now, Table 5.2, it says, "The probability of large steam LOCA . . . train A is 5E to the minus one." It doesn't make any sense to me. The probability of the LOCA is .5? This is Table 5.2, 5-2.

MR. WACHOWIAK: Your notes?

MEMBER WALLIS: My notes on page 5.5-D. Well, if the probability of a LOCA is .5, I wouldn't have built a plant at all. I don't understand what that number means. Is that the initiation of this whole --

MR. WACHOWIAK: That would not be the initiation that we --

MEMBER WALLIS: It doesn't make sense.

MR. WACHOWIAK: I'm not sure of the origin of that value or the context that it's used off the top of my head.

MEMBER WALLIS: Well, maybe someone can answer that later in the day.

MR. WACHOWIAK: Yes.

CHAIRMAN APOSTOLAKIS: The large LOCA, Graham?

MEMBER WALLIS: It says, "Probability of LSLOCA" -- large steam LOCA I guess that means -- "in FWTA," FW train A, point -- well, you can look into those, but there's some numbers in that table that are really strange, strangely high. It's Table 5-2, and in my version it's page 5.5-D.

MR. WACHOWIAK: The specific acronym you're saying is -- can you read that off?

MEMBER WALLIS: It says, "Probably of LSLOCA."

MR. WACHOWIAK: LSLOCA.

MEMBER WALLIS: That means large steam LOCA, right? Does it mean that? In feedwater train A.

MR. WACHOWIAK: We'll find that out, see what happened there.

MEMBER WALLIS: Now, maybe if train B is okay, but train A is in trouble.

CHAIRMAN APOSTOLAKIS: Now, I think the subcommittee would very much like to see a detailed discussion here of the dominant sequences.

MR. WACHOWIAK: Okay.

CHAIRMAN APOSTOLAKIS: Okay? Like this sequencing the loss of prepared power and two or three others. So maybe at the next meeting we can do that.

MR. WACHOWIAK: Okay.

CHAIRMAN APOSTOLAKIS: Walk us through it. Tell us what the data used were, where they came from, common cause failures, the whole works. That would be a useful thing to see. Okay? So that's another item for the future.

So initiating events.

MR. WACHOWIAK: We'll talk about what we used for initiating events. We covered the spectrum of transients, grouping them as appropriate, various loss of coolant accidents. Basically the reason we split those up is that where the different penetrations come into the vessel makes a difference somewhat in how the response is and what the actual outcome is going into the Level 2.

MEMBER WALLIS: What does loss of the condenser entail? The condenser is three. You don't have any water flowing through the coolant side or something?

MR. WACHOWIAK: It could be several things. You could lose the water on the cooling side. You could lose the vacuum so that you get a hole and--

MEMBER SIEBER: Air bound.

MR. WACHOWIAK: -- air bound.

MEMBER WALLIS: It's more likely that you partially lost it, isn't it? For some reason the vacuum doesn't work very well or something. Again, all of these things are extreme cases. Certainly it isn't there, which seems to be very unlikely.

MR. WACHOWIAK: Then in those cases what we have to look at is what I think is on the next slide, is going back to how we got those numbers, and if you go into the NUREG, it gives a list of where the various numbers came from, and things like partial losses of condenser were either included or excluded in all those different values, and we summed up the ones where the failure mode is still retained in the ESBWR even though we may have augmented the design so that some of these failure modes for transients --

MEMBER WALLIS: That's also bothered me. You go back to this NUREG, which is based on past history. You're going to build a much better plant.

MR. WACHOWIAK: That's right.

MEMBER WALLIS: The condenser won't look quite like all of the old condensers, and yet you're going to use the same number for its failure because that's all you've got? Is that it?

MR. WACHOWIAK: Well, there's two things. There's one, we do have it. That's always a plus. It's always good to go with something that you do have.

But our objective here on the PRA is to identify things that are associated with the mitigating features of the plant. We're not necessarily trying to reduce the CDF just by saying, well, we're going to eliminate or reduce the initiating event frequencies because remember, once again, initiating events especially on the transient side aren't necessarily hardware issues. It's hardware and people issues, and what we thought would be a good representation for this phase of the design is to use the values that were based on operating experience at plants, propagate them through the analysis, show that the configuration of the plant can withstand those, and if in the end we do find out that we have a reduced initiator frequency for something because we can prove that the design is better than what's out there, then in a later stage we may use that, or maybe we save that until we get to the operational PRA after we actually have some real data with operating these new systems.

So we made the decision to use the existing database for initiating events, and the only place where we really took things out is if something in the existing database, that feature or that failure mode that was there just isn't there anymore in the ESBWR. We took some of those out. So there are some tweaks on the values, but they were fairly consistent.

The other thing that we did with this is in the LOCA frequencies. Now, you saw we had a whole bunch of different LOCAs there on the previous page, and you can't go into any of these documents and find where is the GDCS line break or where is a -- you know, they're based on existing plant type numbers.

So what we did to get to our LOCA numbers was we looked at how it was done, how it was apportioned for the existing plants, used the same values, but just reapportioned those values associated with the piping sizes and classes that we have in this plant.

So it's essentially the same LOCA values that were used that were found in the other documents, just reapportioned.

MEMBER WALLIS: So when do you use the valves which you're going to stick open? You use exactly the same valves in 2020 when you build this reactor as were operating experience in 1987 to 1995? Nothing has improved in 25 years?

MR. WACHOWIAK: We expect improvement in 25 years, but the key that we wanted to say is that the reason -- we don't want to eliminate consideration of I'll call it vulnerabilities, but consideration for certain sequences just because we're speculating that 20 years from now we're going to have better SRVs.

CHAIRMAN APOSTOLAKIS: The question is: is it worth the effort to argue with he NRC staff --

MEMBER WALLIS: That's it.

CHAIRMAN APOSTOLAKIS: -- why you use a lower probability distribution when, in fact, it doesn't seem to affect much?

MEMBER WALLIS: The whole process, the whole regulatory process seems to inhibit improvement.

CHAIRMAN APOSTOLAKIS: To some exhibit.

MEMBER WALLIS: Because you know some number that's 40 years out of date, and you know it and it has been approved, we'll stick with it and we won't try to do any better.

PARTICIPANT: Or increased margin.

MEMBER DENNING: But during the operation, they'll --

MEMBER WALLIS: You will see that.

CHAIRMAN APOSTOLAKIS: On the other extreme you have people who, you know, and you see that mostly in the aerospace business. We change the design and, boy, they hit the failure rate by a factor of ten or 20, and then of course, nobody believes it. So I think what these guys are doing is much better, staying with the numbers even though you know that the distribution will make it have shifted.

MR. WACHOWIAK: In our optimization of the design, if we find out that one of these assumptions for something that we know is going to be better is impacting other parts of the design, like, you know, because we did this now we have to have -- I don't know -- MSIDs that weigh a million pounds. I don't know. Something that affects the rest of the time. Then we can take a hard look at those and see if there's something that we can do.

But for the cut-through that we're doing at this phase, we thought it prudent to look at existing operating experience, initiating events that come from all sorts of different things, not just from looking at a particular design or some component or some system.

And I think I've covered everything on here.

CHAIRMAN APOSTOLAKIS: Yeah, you've covered it.

MR. WACHOWIAK: Basic event data. Now, this is another one of these places where we had to do something. We needed to use generic data

CHAIRMAN APOSTOLAKIS: How old is the URD? I mean, that's a long time ago, isn't it?

MR. WACHOWIAK: Yes.

CHAIRMAN APOSTOLAKIS: How old is it?

MR. WACHOWIAK: How old is it?

CHAIRMAN APOSTOLAKIS: '80s, late '80s?

MR. WACHOWIAK: '80s sounds correct.

CHAIRMAN APOSTOLAKIS: They assure me there have been PRAs for BWRs all over the place. I mean, why didn't you use those, or did you check and the numbers were more or less the same?

Because the later PRAs probably include plant specific information. They are more realistic numbers. I don't think it's a major issue, but I'm just curious. I mean, just because it's a document blessed by somebody, we have to stick to it?

MEMBER WALLIS: Yes.

MR. WACHOWIAK: It's more coming from our customers' request that we use the URD as a --

CHAIRMAN APOSTOLAKIS: I see.

MR. WACHOWIAK: -- guide for our design, and the data that's in there is included in that table.

Now, we did look through there and compared it to things that we used in the Lungmen plant which we're building now in Taiwan. We've got a PRA for that. We have some experience from other things factored in, but we've looked at some of these failure rates with respect to the group's experience from looking at operating plants.

We're not seeing, you know, orders of magnitude difference in these values. So I think at this phase of the design, I think the good enough principle applies here.

Now, if there's something that is very important and we address some of these in the sensitivities; we looked at these new squib valves. Is the reliability in the URD for squib valves, is that appropriate for what we're using here? And we tried to see if there was some kind of sensitivity to that. There is some sensitivity, not necessarily enough to change our minds on things, but generally that's where we get them from, and we think that it's a conservative way to go.

It can be refined in the future, but you know, with some of the new equipment, we're not really going to know until we operate and start testing some of these things.

CHAIRMAN APOSTOLAKIS: Speaking of the squib valves, I didn't want to raise it, but you did. On Table 4.6-5, list of system common cause failures, this is the gravity driven system. There is a probability of the common cause failure of all squib valves equal to three times ten to the minus five.

And the probability -- oh, no, I'm sorry. For two valves, for two squib valves is ten to the minus five, 3.6, ten to the minus five. The probability of one valve failing is three, ten to the minus three. So if you're going to take the ratio, I come up with a beta factor of .012.

Now, the beta factor usually is around ten percent, and you are going here with one percent, and I wonder how that came about.

MR. WACHOWIAK: Well --

CHAIRMAN APOSTOLAKIS: One percent is pretty low.

MR. WACHOWIAK: Ten percent seems fairly high.

CHAIRMAN APOSTOLAKIS: But that's the number that --

PARTICIPANTS: No, no.

CHAIRMAN APOSTOLAKIS: First of all, that's one of the problems with PRA. I mean, we are dealing with all of this as if they were nothing, you know. I don't like that percent. Make it one percent or make it one in 1,000.

Well, it could be .06, right? It doesn't go down by an order, but let me -- no. I mean there's very strong evidence that the beta factors above .1, extremely strong, in fact, based on data. In some cases it's close to .2, okay, and I have a figure if you'd like. I'll send it to you, where there is all sorts of information, and the average is about .1.

MEMBER WALLIS: Is this just for squib

valves or for --

CHAIRMAN APOSTOLAKIS: No, no, for all kinds of components.

MEMBER WALLIS: Everything.

CHAIRMAN APOSTOLAKIS: Interestingly enough, for space systems it's also .1, and people now are scratching their head. What's magical about .1?

But anyway, but the bigger factor here of .012, it seems to me, has to be justified on the basis of something, and again, you don't have to answer now, but next time, these are the kinds of questions you're going to get.

MR. WACHOWIAK: Okay.

CHAIRMAN APOSTOLAKIS: It's awfully low. It's awfully low, in my view. I mean, there is no basis for it. Okay?

Now, for four valves, I understand that. In fact, another thing is for four valves, only four squib valves fail to open. It's three, ten to the minus five. For two valves, its 3.6, ten to the minus five. I mean, that's incredible accuracy.

MEMBER WALLIS: Well, there are some more accurate figures in some other tables.

CHAIRMAN APOSTOLAKIS: And then the CCF for all seven squib valves in the GDCS lines, failure to open is 1.5, ten to the minus five. That indicates sensitivity of the model to the number of valves that I don't believe is there.

So all of this is on the transcript now. Next time we discuss this, right?

MR. WACHOWIAK: Okay. We can discuss how we got those different common causes.

CHAIRMAN APOSTOLAKIS: Yeah. You say you used the alpha factor method, but one of the key elements in the methodology that the NRC and EPRI have developed is that you go back and look at actual common cause failures and you screen out the ones that don't apply to you, and I don't know whether you did that, but if you did that, then you probably screened out more than you should have.

MEMBER WALLIS: Well, I think in order to achieve credibility, you have to look at some of these things in the detail that George is looking at it, and you folks have to justify what you did.

CHAIRMAN APOSTOLAKIS: Yeah, because you know, the last line there says "low CDF to design rather than data values." Well, I just showed you a data value that may be a driver, in fact, because in order of magnitude it's an order of magnitude. You know, an order here, an order there. Pretty soon you're talking about pretty low values.

I'm not saying I'm right. I'm saying we need an answer to what I just said.

MR. WACHOWIAK: We will discuss that.

CHAIRMAN APOSTOLAKIS: Very good.

MR. WACHOWIAK: I did want to bring up one other point here, is that we do have components that in this plant we don't expect to be tested except on a refueling interval basis, and if we use demand data from some of these generic sources from that, some data are actually based on quarterly type test intervals. So we adjusted those, basically converted the quarterly test interval data into an hourly rate and we applied a longer test interval.

CHAIRMAN APOSTOLAKIS: Yeah, the results of the problem there, unfortunately I cannot find it now, but you used some formulas to do some things that are not clear to me what they mean, and we definitely need some explanation in the future.

MR. WACHOWIAK: Okay.

CHAIRMAN APOSTOLAKIS: How you did that. You said, you know, using well known formulas this is where we got, and I hope I'll find it and let you know where it is.

MR. WACHOWIAK: Okay. That would be in --

CHAIRMAN APOSTOLAKIS: Failure rates, you know, how they were --

MR. WACHOWIAK: In Rev. 1 we included what the formulas were.

CHAIRMAN APOSTOLAKIS: Oh, I don't know which rev. I looked at. Oh, okay. I found it. I found it. It's in Section 5.2 of the PRA. Okay? Component reliability database, 5.2.

So if you guys come back later and address these issues, for test periods greater than a year, this is what we do. For others we do something else. For components whose test period is from six months to one year it is suggested that the upper bound on demand failure probability be used as a computation of mean, the median, and then the new mean is that value times the error factor.

That's not true. So not that it makes a hell of a difference, but we don't want to -- in addition to the typos to have also --

MEMBER WALLIS: I think you need to look at it, and the same thing in thermal hydraulics. The devil is often in the details.

CHAIRMAN APOSTOLAKIS: Yes.

MEMBER WALLIS: And you find something which is unjustifiable in the details sometimes.

CHAIRMAN APOSTOLAKIS: In the details, of course, what they do is they create an image, a section.

MEMBER WALLIS: Absolutely. You don't need many false details to discredit the whole thing.

CHAIRMAN APOSTOLAKIS: Yeah. So please look at that in Chapter 5, 5.2, and then we know we'll talk about it. Okay? Good.

Human actions.

MR. WACHOWIAK: Human actions. This will probably be another one that you're going to want to have --

CHAIRMAN APOSTOLAKIS: I suspect it will be, yes.

MR. WACHOWIAK: But at this stage of the game of the design, we did a very simplified version of human actions. We looked at two different things, pre-accident actions. Basically it was looking for places where we expected maintenance to potentially leave systems in an unknown unavailable state.

Then we looked at what controls were placed on some of these things to see if there was something that we could do with quantification. For things where we just relied on check lists or just standard things that the plants do, we kept the standard value. If there were additional controls like alarms or indications or things, we would do different things.

We took the most credit when it was, you know -- and alarmed in the control room stayed on these valves.

MEMBER WALLIS: I'm just looking at my notes. I wrote on one page here where you were looking at some -- "operator errors are judged to be a non-significant contribution." I think you're talking here about operation of depressurization valves or something.

But it's just an assertion. There's no explanation of why, and I just wonder how many of these sorts of statements are allowed in the PRA. You simply say we judge something to be nonsignificant without any justification, particularly operator actions. How do you really know what they're going to do unless you've got some basis, how they perform on a simulator or something?

So I just picked it out and we should ask why whenever we see statements like that.

MR. WACHOWIAK: Was that related to the error of commission or was that related to --

MEMBER WALLIS: Well, I'm not sure. I'd

have to look at page 2.3-4 to see the context, but this is the kind of thing I pulled out.

MR. WACHOWIAK: Two, point, three, dash, four, assuming initiating events.

MEMBER WALLIS: Right. It's an initiating event, isn't it?

MR. WACHOWIAK: Right.

MEMBER WALLIS: Yes, okay.

MR. WACHOWIAK: So in that context --

MEMBER WALLIS: I think it was opening a valve when they shouldn't do it or something

MR. WACHOWIAK: Yeah, it was causing an initiating event.

MEMBER WALLIS: Causing an initiating event.

MR. WACHOWIAK: By doing something that they --

MEMBER WALLIS: And you just said that so you assume they won't do it.

CHAIRMAN APOSTOLAKIS: Yeah, you are right. We will need to have a special session on these things, especially tables --

MEMBER WALLIS: Well, how long are you going to take though? If you go into the details, it's going to take a long time.

CHAIRMAN APOSTOLAKIS: Well, it could be a two day meeting. Table 6-1 and 6-2, actually 6-2 is fascinating. You have --

MEMBER WALLIS: Where are we here?

CHAIRMAN APOSTOLAKIS: It's probably -- the numbers you have there probably come from the EPRI ACR model, right? One called the reliability model.

MR. WACHOWIAK: Yes, that sounds right.

CHAIRMAN APOSTOLAKIS: And if they do, you are probably the only organization at work that's using it, and you have are remarkable table here. You are giving us probabilities of failure as a function of time, available time, 30 minutes, 60 minutes --

MEMBER WALLIS: Aren't they all one year minus one, one year minus two, one year minus three?

CHAIRMAN APOSTOLAKIS: Yeah, and also you are classifying them according to the behavior type, skill, rule and knowledge. So this is really a remarkable achievement here.

MEMBER WALLIS: I say it must be very rough estimates in my notes.

CHAIRMAN APOSTOLAKIS: But the thing is that this is of great interest to some of us on this committee because we're trying in another context to convince the NRC staff that we do need time dependent

-- I mean the distribution for the probability of failure given the time.

But this is definitely something -- you say you are relying on EPRI NUREG CR-1278 and NUREG CR --

MEMBER WALLIS: Is that Table 6-1 there, too?

CHAIRMAN APOSTOLAKIS: Yes, there is a 6-1, but that is pre-initiated.

MEMBER WALLIS: A detection interval of 8,640 --

CHAIRMAN APOSTOLAKIS: That's one year.

MEMBER WALLIS: That's a pretty long time.

CHAIRMAN APOSTOLAKIS: No, they don't mean detection. You mean inspection, I think, human inspections.

MR. WACHOWIAK: That's inspection.

MEMBER WALLIS: It says detection.

CHAIRMAN APOSTOLAKIS: It says detection.

MR. WACHOWIAK: Detection, it's from when you operate it this time until when you go back and operate it again.

MEMBER WALLIS: Oh, it doesn't mean it takes a year to figure out what's going on.

CHAIRMAN APOSTOLAKIS: It's the interval

between tests.

MEMBER WALLIS: I thought it meant that it would take him a year to figure it out. Me, too.

MR. WACHOWIAK: It is from when we make a mistake until we believe there's opportunity to discover it.

CHAIRMAN APOSTOLAKIS: It's the degree of detection, right?

MR. WACHOWIAK: Yes.

CHAIRMAN APOSTOLAKIS: Between tests. Detection is the wrong word.

MR. WACHOWIAK: I believe detection is correct because it might be between tests or it might be between operation. Like let's say it's an FAPCS valve and they go to do a full water transfer and they say they got water on the wrong place. Oh, we detect it when we're doing this other operation.

So it's when you can detect it. Sometimes it's test interval. Sometimes it's operation intervals.

CHAIRMAN APOSTOLAKIS: the problem with detection is that it's also used in other contexts.

Anyway, these are the tables we needed, 6-1, 6-2.

MEMBER WALLIS: Almost every table can be questioned.

CHAIRMAN APOSTOLAKIS: The whole Chapter 6.

MR. WACHOWIAK: The tables in Chapter 6, and one of the things that we'll talk about that and now it looks like where we'll be for quite some time until all of the human factors analysis and all of those things are wrapped up, we're probably going to be retaining this type of structure for the next year, year and a half or so before it gets significantly changed in the PRA.

So if you would have asked me this six months ago, I would have said we're probably going to go to something different in the future, but now I think that's a good topic because I think that the way the schedule is working out, we'll be using this for some time.

CHAIRMAN APOSTOLAKIS: Well, yeah, but also at the same time you want to do something that's reasonably defensible, right?

You know, I hear mixed comments regarding this AHCR model, even from the original developers.

MR. WACHOWIAK: Okay.

CHAIRMAN APOSTOLAKIS: I think it would behoove you to go and talk to one or two of those guys. Give them a call. I mean, what's going on with these models?

You know, they run simulator experiments, you know. Then we hear that they were overly enthusiastic in using the results of the experiments to produce these numbers. I don't know what to believe myself, and we had a subcommittee meeting on human reliability about a year ago, last December, well, last December, and some folks from the utilities and EPRI presented their calculator, the APRI calculator, which allows you to use -- it's really a problem that allows you to use one of four models.

One of the four models is the AHCR, and the guy from the utility told us nobody is using it. Do you remember that. Do you remember that?

PARTICIPANT: Yes.

CHAIRMAN APOSTOLAKIS: So now if nobody is using it and you're the only ones, I'd like to understand why. I think I know why. Because it's the only model that gives you information like what you have in 6-2, time and probability of failure.

MR. WACHOWIAK: And it's somewhat independent of the variables that we don't know at this point in time.

CHAIRMAN APOSTOLAKIS: Anyway, I think

it's something to look into.

MR. WACHOWIAK: Okay. In the end, one thing that we didn't include in the PRA is the repair and recovery in the base model. We did look at recovery of off-site power based on the NUREG curves, so the loss of off-site power from 1992 through -- or '82 through 2006 I think are the latest one.

I want to back up. One --

MEMBER BONACA: One comment regarding the previous slide.

MR. WACHOWIAK: Yeah.

MEMBER BONACA: I think to me interesting is also how do you -- you know, you had configurations, and you identified that because for a certain system you have a lot of involvement that is maintained and taken out and in. Okay. You could really improve the safety of the plant by modifying maybe that system there.

Have you had any -- how do you --

MR. WACHOWIAK: Modifying the which system?

MEMBER BONACA: I mean the plant.

MR. WACHOWIAK: Oh, okay.

MEMBER BONACA: Well, take the CRDF system. I mean, you have so many valves there, you know, butanized to a valve being persistent or, you know, each line and then tested and so on and so forth. Is there any better way to do it?

I mean, I'm trying to understand how do you use the PRA to give an input to design. Here you're talking about modeling this human actions, but it seems to me that you have the opportunity to modify the necessary human action at this stage of design, and that's what I would like to understand at some point, not necessarily today, but at some point I'd like to understand how you came to this ESBWR.

How did the PRA contribute to it?

CHAIRMAN APOSTOLAKIS: I think, Mario, part of it was in the original utility requirement where they decided that for the first what, 24 hours, 72 hours? The design should not require any operator intervention.

MEMBER BONACA: Yeah. No, I understand.

CHAIRMAN APOSTOLAKIS: So they just followed up, right?

MR. WACHOWIAK: The design matches that. In our model here, we look at some of these active systems that can be actuated using operator actions. We do look at a sensitivity that says what happens if we do analyze it the way the ERD said no operator actions for 72 hours and take a look at the effect of the overall results on that and the revision to that analysis is in the process of being updated before that's done.

So we do look at it in that sense, but I think the place where we're more going to use this is as we develop our instrument and control systems for the plant and the layout for the simulator and after the simulator, for the control room and for the remote shutdown panel, and where different actions need to take place.

Where we find in the PRA some of these actions to be important actions, we might say, you know, maybe you want to put that somehow in the automated system or maybe you want to insure that that's in the control room and not out in the field.

That would be the way that we would use that, but at this point in the overall scheme, all we've gotten to is identifying the higher level operator actions to the people that are doing the human factors analysis. So when they go through their process, we'll be factoring this sort of thing into it.

So that's the process for doing it. We've identified what's important and then modeling of that goes into the way that the human interface is put together from the plant, and then we'll be able to come back later and see if we did any good or if it didn't make much difference, but I think we can do that. We're just on the front end of it right now.

CHAIRMAN APOSTOLAKIS: So in one of your sensitivity analyses you assumed that all the human actions --x

MR. WACHOWIAK: Prevailed. All the post.

CHAIRMAN APOSTOLAKIS: Post initiated.

MR. WACHOWIAK: Post initiated actions are failed, except for the recovery of off-site power. That's one where the typical thinking for that was the grid associated loss of off-site power, and it would be different people addressing that, but there are contributions from the things that are on site. So we may want to relook at how we did that if there's any dependence there on the no post accident operator --

MEMBER MAYARD: Even though off-site power may be restored, the operator still would have some action, closing some breakers to get power into the plant.

MR. WACHOWIAK: Yes, that's one of those areas where we made the statement, "Yes, we did that." I'm not quite sure we recognized that those recovery factors really imply operator actions when we did it.

And we recognize that. I think that's getting into Rev. 1 of that part of the analysis. So it's another thing to verify.

Oh, I know why I went back. I left something off the slide. Part of the process that we did look at is on the back end. You know, you put all of these things in your fault tree models, and you could end up with cut sets that have a whole bunch of different operator actions in them. We did do an evaluation of the cut sets to make sure that we didn't have any highly dependent operator actions there.

There were a couple of things that either they weren't dependent or they didn't exist or we did a judgment call. Really are the two operator actions together -- is the value that was used sufficiently high that it really would be expected to cover the combined action? That would be the case where we would have some of those, where there are .2 for operator actions, .2 times .2 for the double actions, probably like a range where we'd expect anyway. So that process went through on the back end to look at those.

I think we talked about the success criteria a little bit earlier. Hand calculations, bounding type things for things that we just knew the answer to ahead of time. Design basis assumptions for things that matched up well with the Track G analysis, and then we used MAAP results for the other things.

We're in the process now of resolving where we should be between that and track. When we did look at the success criteria, the way we arranged this was we didn't just say this system, what does it have to do. We looked at it in the context of the sequences where the systems were used, took a look at all the sequences, looked at the different attributes of those sequences and determined if there were any specific limiting sequences to use for that success criteria, and we used it all.

So in some cases the success criteria might be conservative, but we tried to apply the same success criteria to the same functions throughout the PRA just to make it simpler for analysis purposes.

We're working on a topical for this that we've been discussing with Nick and others.

CHAIRMAN APOSTOLAKIS: You say all sequences reviewed. Was the PRA reviewed by anybody?

MR. WACHOWIAK: What I meant there was when we were determining the success criteria, we didn't just look at a system in isolation. We looked at the system as to how it was used in the sequences where it was used in the PRA. So we looked at all of those. All of the sequences of a particular system was credited for success.

Then what we did was we went through that list and said, okay, what are the attributes of these different sequences, and is there any one particular sequence or one or more -- actually on some there were two sequences -- that really would make that a more limiting success criteria on that particular function?

And the ones that were the limiting, that had the limiting attributes were the ones that we used to determine the success criteria for the system.

CHAIRMAN APOSTOLAKIS: Yeah, I understand that, but this is a broader threshold now.

MR. WACHOWIAK: Okay.

CHAIRMAN APOSTOLAKIS: Did you have a group reviewing the PRA itself?

MR. WACHOWIAK: Outside of this project, no. So we got various contractors and subcontractors looking at different things, but they were all under the task that I am.

CHAIRMAN APOSTOLAKIS: Because you mentioned the ASME standard, and as you know, there is a PRA review requirement there. Of course, I mean, in this design certification business, what is the role of the PRA? Because in the ASME standard you are supposed to use it for some real action. So the PRA is very important.

But here my feeling is that this is really a supporting kind of analysis. It's not essential, isn't it? Maybe the staff can answer that.

I mean, does the PRA have to be PRA reviewed?

MS. CUBBAGE: I mean, it is a requirement in Part 52 that they do submit the PRA, and it is primarily used to insure that the insights have been incorporated in any design requirements that were out of the PRA are factored into the design.

But I guess to some extent you're right. It is more of a supportive tool, and it also helps us guide our review to the more risk significant areas.

CHAIRMAN APOSTOLAKIS: The moment you say "insights," it sends a message. Don't do it. Any time you use the word "insights," not you personally. I think that the word "insights" should be banned from the English language.

"Insights" means made by the state of the art or state of the practice job, but they gained insights, and 52, of course, says that, but there is not a drive for the PRA to be peer reviewed.

If we do a minor change in an existing LWR, we demand all sorts of PRA reviews, but from this thing, no.

MEMBER BONACA: -- at some point between conceptual design and completion of the plan. The PRA will be in a situation where, in fact, the peer review is worthwhile. I think at this stage I'm not sure that I would consider it worthwhile.

CHAIRMAN APOSTOLAKIS: Worthwhile and required are two different things. If the owner of the ESBWR decides not to do anything on a risk informed basis, his PRA does not have to be peer reviewed. Only when the owner says, "I'm going to invoke 1174."

MEMBER BONACA: I'm only talking about -- you know, I would expect that this PRA would be much more substantial when we can close up --

CHAIRMAN APOSTOLAKIS: Sure.

MEMBER BONACA: So at that point I would expect that there would be a higher expectation.

CHAIRMAN APOSTOLAKIS: No, but as Nick said already, that time is running out. I mean, if you have a peer review group that comes back and says, "We don't like the HRA," you would say, "I'm not going to change," unless they say, "Well, then we resign."

Because, you know, there are certain things that are cast in stone, as you are advised. Anyway, there is no requirement. You haven't done it, that's fine. Let's move on.

MR. WACHOWIAK: We do remember though that the part of the process that we're talking about here and that we talked about this morning is we intend to deliver a PRA to the plant that will be operated, and they will use that PRA. So somewhere before we get to that stage, they've got to have that or else they don't have the complete package.

So the question is when, not if.

MEMBER ARMIJO: In your internal procedures, I'm sure you have internal design reviews by independent parties, but whether that has to go outside of General Electric to some other peer review I don't know, but certainly before you would issue a document like that to the utilities, you would have an independent design review of the work done to satisfy your management that you've got a quality product.

MEMBER SIEBER: QA program.

MEMBER ARMIJO: Yeah, more, I guess, from QA.

CHAIRMAN APOSTOLAKIS: Okay. Let's go on.

That's the bottom line. Why are you reporting 310 to the minus eight when Chapter 11 you say that the mean value is eight, ten to the minus -- what is this 310 to the minus eight? It's the median? It must be the median.

MR. WACHOWIAK: This is the value that you get when you use the point estimates for all of the values. Now, what's in Chapter 11 using the simulation code --

CHAIRMAN APOSTOLAKIS: Yeah, you've got the on site.

MR. WACHOWIAK: -- the mean looks like it comes out to be a different value.

CHAIRMAN APOSTOLAKIS: It is eight, ten to the minus eight, and I believe that's the number you should be reporting. I mean all of the regulatory documents refer to mean times. I mean it's not a big deal. It's just problematic.

MEMBER WALLIS: What's the worst it can be?

CHAIRMAN APOSTOLAKIS: The 95th percentile is around two, ten to the minus seven.

MEMBER WALLIS: There's one up at E minus five.

CHAIRMAN APOSTOLAKIS: No, no, no, no. The 95th percentile.

MEMBER WALLIS: Yeah, I know.

CHAIRMAN APOSTOLAKIS: Which is remarkable, remarkably narrow, right? Think about it. This is the media, 310 to the minus eight, and the upper bound is maybe four times that, a narrow factor of four for a design that has never been built, right?

MEMBER WALLIS: Why is frequency on log scale? This is not log or is it frequency?

CHAIRMAN APOSTOLAKIS: This is log.

MEMBER WALLIS: Frequency. I had a little trouble.

CHAIRMAN APOSTOLAKIS: No, this is the frequency. This is 1.10, ten to the minus --

MEMBER WALLIS: No, it depends on the scale.

CHAIRMAN APOSTOLAKIS: No, but this is from the computer probability.

MEMBER WALLIS: Yeah, but is it probability per unit of logarithmic increment or --

MEMBER DENNING: It looks like it is. See, these are equal logarithmic --

CHAIRMAN APOSTOLAKIS: This is the table. The table is the result of the simulation. It says the upper bound to the core damage frequency is 1.8, ten to the minus seven.

MEMBER WALLIS: What is the mean?

CHAIRMAN APOSTOLAKIS: The mean is eight, ten to the minus eight. I think you should report the mean.

MEMBER WALLIS: Well, I have a problem. Is it plotted on a log scale? Now, I concluded from their numbers up here that they must be probably for unit of frequency, not per unit of log frequency. It's actually different.

CHAIRMAN APOSTOLAKIS: Forget about the figure. The figure is just for communications. The table is actually from the computer.

MEMBER WALLIS: So it's the table.

CHAIRMAN APOSTOLAKIS: The table, yes.

MR. WACHOWIAK: Both are from the computer program.

CHAIRMAN APOSTOLAKIS: The table is the real frequencies.

MR. WACHOWIAK: Yes.

CHAIRMAN APOSTOLAKIS: Okay.

MR. WACHOWIAK: One of the difficulties --

CHAIRMAN APOSTOLAKIS: I mean does it bother you to report eight, ten to the minus eight?

You seem to be --

MEMBER SIEBER: He's happy.

CHAIRMAN APOSTOLAKIS: For heaven's sake, that's low. It's way low actually.

MEMBER SIEBER: We're falling into the sun.

MR. WACHOWIAK: To try to compare things on an equal basis then, using that value in the mean from that particular computer program would be problematic for us because of all the different places where we're trying to compare. For the different scenarios, the fire, the floor and everything else, this number is what's comparable across the different ones.

So I understand. I understand what you're saying there, and we will investigate how to present this. It generates difficulties in talking about things like raw values and things. If you take that mean from there when the computer program is calculating all of these other values using this number.

CHAIRMAN APOSTOLAKIS: But it should be using the mean, but that's easy to do.

Anyway, do you know that the age of the earth's crust is 310 to the ninth years?

MR. WACHOWIAK: Yes.

CHAIRMAN APOSTOLAKIS: So what you're saying here is that if we had a reactor built when the earth's crust will start to forming and we had to run it then, then you are just an order of magnitude worse than that. It's an incredible number, isn't it? Ten to the minus eight.

MR. WACHOWIAK: What we're trying to say here is that for just about anything that we could think of, we've found a way plus a diverse way of dealing with it, and in most cases more than that. So what we're trying to say here, and I think we've used this in other presentations before is that we think we've addressed everything that we know.

MEMBER WALLIS: This is where actually permission to comment, I mean, just to talk about disgruntled employees rather than any other kind of event, but people doing things to deliberately cause an event really begins to be very important when you have numbers like this for the things that you analyze.

MEMBER MAYARD: Yeah, but one of the things that we tend to not take into account from the human performance standpoint are the positive attributes, like they did not take any repair activities into account.

CHAIRMAN APOSTOLAKIS: Oh, I know that.

MEMBER MAYARD: And if you don't watch any of your emergency planning scenarios and stuff, what the human can do from a maintenance, design, modification, a lot of things that they can do that we never take positive credit for in a PRA. So --

MEMBER WALLIS: The probability of an operator going absolutely nuts is probably bigger than ten to the minus eight.

CHAIRMAN APOSTOLAKIS: I think most of them dominate this culture.

MR. WACHOWIAK: It's tentative.

MR. WACHOWIAK: Well, I think what we're trying to accomplish here is to address the things that we know about and the things that we can know about using this methodology. Is that the actual core damage frequency? Well, we don't know because there's things we don't know about, and maybe there's other tools that are better for doing that.

But for using this method, we think we've addressed just about everything associated with the design of this plant to make the chance of a core damage event so remote that we aren't, that it's a vulnerability that's been addressed. We don't see that anymore.

So I agree that there might be something out there that isn't included that could address core damage frequency, and it's probably things that can't be addressed using these methodologies.

CHAIRMAN APOSTOLAKIS: Let me ask you something else. I mean, we're going now to a different place. It is tempting to me to go back to the beginning of the use of PRA now that you ask. It's up to you. Look at the numbers we were producing at the time, although the reactor safety numbers were not that bad, and then see what happens in the intervening years, how many times we were surprised and knew things happened and so on, and this agency had to promulgate extra rules.

Doesn't history apply here? Can I count the number of times I was surprised in the past and say, well, gee, maybe in the future I'll be surprised. Therefore, is there anything different here?

MR. WACHOWIAK: I wouldn't discount being surprised in the future.

CHAIRMAN APOSTOLAKIS: But is it a different situation? I think in some sense it is because --

MR. WACHOWIAK: But I think it is a

different situation.

CHAIRMAN APOSTOLAKIS: -- you have just said that we are eliminating a lot of the stuff we learn from experience in the NWR.

MR. WACHOWIAK: That's right.

CHAIRMAN APOSTOLAKIS: So we didn't have that benefit at that time, but you know, I remember the first PRA topical meeting in Newport Beach, California, where everybody was reporting for -- you know, we did a fault tree analysis for this system, and the magic number was ten to the minus six, which became ten to the minus four as people came to their senses.

So I don't know. I don't think you or I or anybody has an answer to that, but this is something, I mean, when you go to such low numbers and you have new designs that have never been billed. You really have to worry about these things. That's where structure of this defense in depth comes to the rescue.

MEMBER WALLIS: Well, they don't need a containment if they've got ten to the minus eight.

CHAIRMAN APOSTOLAKIS: We are way over time here.

MEMBER WALLIS: Are we or not? Is he

going to finish up?

CHAIRMAN APOSTOLAKIS: We're supposed to finish at 11:30. He is so slow.

(Laughter.)

MR. WACHOWIAK: Just a few more pages.

MEMBER WALLIS: This is a very funny figure to me.

CHAIRMAN APOSTOLAKIS: Which one is funny? This one?

MR. WACHOWIAK: This figure here.

MEMBER WALLIS: I would conclude that you way over designed your LOCA response and you way under designed your loss of power. I mean, if that's the dominant thing, maybe you should have another diesel or something. Maybe you can relax your LOCA defense.

MR. WACHOWIAK: The actual thing is the loss of feedwater, is what's --

MEMBER WALLIS: You can do something about that, bring on more pumps or something.

MR. WACHOWIAK: The loss of power causes a loss of feedwater.

CHAIRMAN APOSTOLAKIS: I mean these event trees are awfully similar, aren't they?

MEMBER MAYARD: We don't want to penalize them though for wearing down the --

(Laughter.)

MEMBER WALLIS: It's a very funny design. Only susceptible to one major accident.

MEMBER KRESS: That's all right.

MEMBER WALLIS: You can relax your LOCA now. You don't need anything like as much water and all of that stuff because it's --

CHAIRMAN APOSTOLAKIS: No, no, no.

MEMBER WALLIS: That was ten to the minus eight.

CHAIRMAN APOSTOLAKIS: If you relax it, the contributions will change.

MEMBER WALLIS: Once the economists look at it, they'll say, "Wait. How are we paying for this medium LOCA .8"?

MEMBER KRESS: We had a concept once that tried to allocate the risk contributions to various sequences. It just never went anywhere. It was a bad --

MEMBER WALLIS: No, but there is a -- there must be an economic penalty to way over designing for LOCA.

CHAIRMAN APOSTOLAKIS: Well, that's not our business.

MEMBER SIEBER: Not with passive systems.

MEMBER WALLIS: That's why I was surprised though.

CHAIRMAN APOSTOLAKIS: Okay. What do you want to tell us?

MR. WACHOWIAK: I want to say that we understand why this is, and we are looking at that from other reasons because as you said, over designing for a LOCA versus these, the thing that causes this is really more of an operational issue, and we're looking at optimizing it because of operations and economics.

So before we're done, you'll probably see a difference went up there, but not because the PRA is driving that.

We did accomplish what we wanted to do here. Bypass we wanted to be negligible. ATWS we wanted to be negligible. High pressure sequences we wanted to be negligible, and the containment can deal with these.

We think that the design is robust. We have put in, as inputs, things that helped us look at what the design was capable of doing. We think we came to that. The probability of a severe accident, say, it's remote, and we think that -- well, we know that the use of the PRA as a design tool helped insure that because as we went through this process, there are thousands and thousands of things that need to be optimized, and we continue to come back and say, "Okay. What is that going to do in the PRA so that we insure that it stays the way that we like it to be?"

Combination of the passive safety and active non-safety systems and the diversity that we built into this thing because really what gets us to the remote chance of a severe accident based on the techniques and the things that we know about this design.

MEMBER DENNING: But you didn't put up the one that shows now take away the actual systems and what happens.

CHAIRMAN APOSTOLAKIS: Yeah, the sensitivity analysis.

MEMBER DENNING: The sensitivity analysis.

CHAIRMAN APOSTOLAKIS: These are very convincing arguments, and you didn't say anything about them.

MR. WACHOWIAK: Yeah.

CHAIRMAN APOSTOLAKIS: We'll get that next time. Okay?

MR. WACHOWIAK: We could do that next time or we can try to find a slot tomorrow for it.

MEMBER DENNING: That would be nice to

just have a short discussion of it because it is so interesting.

CHAIRMAN APOSTOLAKIS: Seeing all of the active systems.

MR. WACHOWIAK: And we can talk about that, but realize when I talk about those, those are all based on our Rev. 0, and we're in the process of revising that to Rev. 1. So the numbers may be a little bit different when you finally get the whole --

CHAIRMAN APOSTOLAKIS: We have to discuss also this timing business because, you know, if we have a meeting in December and we go into the details and we don't like something and you say it's took late now and we can't change it, I mean, we have a problem.

So have that in mind.

MEMBER WALLIS: They have a problem.

CHAIRMAN APOSTOLAKIS: They have a problem, right. They have. That may be fine, but you know, this is not just a formality.

MR. WACHOWIAK: And I would agree that if we had the meeting in December and that was the conclusion --

CHAIRMAN APOSTOLAKIS: So you guys will contribute to the discussion whenever, the next meeting. Okay?

MR. WACHOWIAK: Okay.

CHAIRMAN APOSTOLAKIS: Okay. Thank you very much. This was very informative.

We'll reconvene at one o'clock.

(Whereupon, at 11:57 a.m., the meeting was recessed for lunch, to reconvene at 1:00 p.m.)

CHAIRMAN APOSTOLAKIS: On the record. Okay. We're on the record.

MR. THEOFANOUS: I'll be covering Chapter 21 of this 33201 and I hope to, by this coverage, to create an opportunity for you to ask questions. Obviously, I cannot cover all the details, but I will try to skim over the whole subject.

The work was done by myself and Professor Dinh who used to work with me until about a year ago and now he is chair of Nuclear Safety at the Stockholm Institute of Technology in Sweden. And what do we mean by severe accident treatment is that we are considering containment integrity threats due to severe accident phenomena. So the part of phenomena we're going to cover this afternoon. I'm not going to cover it myself, but it will be covered in the following discussion, containment integrity due to decay heat removal failures and those failures might occur in the long term. So this is more like a systems question and that's why we're leaving it to be handled separately in a separate positive PRA.

Our approach is an interactive assessment management approach. This is because this is a new reactor basically we're working on. The reactor was just finished in design, we're finishing up some of the design. So we had an opportunity to affect the design to the interest of forwarding the final touches to the reliability of the safety process of this ESBWR.

So we worked on it for about a year and during that time as you will see, we developed a number of new procedures and hardware that we think improve even better this severe accident rate of this reactor. Because of the nature of the passivity of the reactor, because of the very extremely low core damage frequency, we felt that the right way of doing this severe accident treatment was by placing great emphasis on bonding high confidence evaluation. It wouldn't do us any good to say we had a reactor that has 10 to the minus umpteen core damage frequency but now we have high probabilities where we will know very well how the debris may attack the concrete on the floor of this reactor should it ever happen to occur.

And as a result of this high confidence

evaluations that we're ascribing for and emphasis on bonding evaluations, we came up with a number of new procedures and hardware that would aim for eliminating some of those analyses for which we could not accomplish that goal. So our conclusion now is that containment failure is physically unreasonable for all severe accident scenarios except the postulated large steel explosions in very deeply flooded low drywell.

It's not that we're saying that these kinds of scenarios, hypothetically large explosions, we're not saying that they will fail. What we're saying is we can not demonstrate with high confidence and high reliability the assessment that this will be so.

MEMBER WALLIS: Are you saying that --

MR. THEOFANOUS: It's important to point out that it's less than one percent of the core damage frequency falls in that category.

MEMBER WALLIS: You're saying all scenarios, but there is a scenario where the reactor vessel is over pressurized and it pops and that popping of the vessel leads to popping of the containment. You're not talking about that kind of --

MR. THEOFANOUS: No, no. All scenarios that are --

MEMBER WALLIS: You're talking about core melt scenarios.

MR. THEOFANOUS: Core melt scenarios, right. And this scenario that you are suggesting is such an extreme scenario that it's not even showing anywhere in this core damage frequency.

MEMBER WALLIS: It's in the PRA though.

MR. THEOFANOUS: Yes, it's in the PRA. Right. But it's what you call a residual risk. I'll discuss residual risk in a moment.

So the people thought the issues in our assessment that we had to basically consider and then take action on are summarized here. There are just a handful. This is a simplified reactor and we thought it really requires a simplified approach rather than a very complex approach.

So the first question was do we want to go with universal retention. I don't think I need to explain to you universal retention, but it's a very popular scheme now since we developed it a long time ago. It does sound that, and actually I have written papers on that, it does help that not only the ESBWR but all BWRs are ideally suitable for this concept, ideally suitable because they have welded steel and they don't suffer from this focusing effect that created a monetary issue or problem for pressurized water reactors.

Why you decided not to pursue that here, that's because as you know all the boiling water reactors, the lower head is perforated by penetration so that if you really want to make sure that you're going to hold everything inside, you have to support this penetration from falling off. So we suggested that as a possibility because I was very concerned about making sure that this reactor, in fact, I was very concerned about all reactors, we cannot assure the coolability if something should happen.

So I was concerned at least for these new generation reactors that we can assure coolability if ever this was to occur. So I said why don't we put a plate somewhere on the support guide tubes and weld it on there on the outside on the housing so that one supports from the other and in fact, such a plate would not only be good for holding everything up in case a melt came to the lower head, but actually it would be quite beneficial in cutting off the driving force behind velocity steam that would come out in the case of high pressure which also takes care of the so-called containment heating problem. But that deal was not agreeable to the designers and I was corrected and

I forgot to change it here, not really the designers, but the design managers. So they felt that it would be causing a lot of problems with the maintenance, the operation.

Then as we were discussing those things, then we came up with another idea that we thought at the end actually may be awfully better. So sometimes there's a silver lining. Sometimes it's better to find some difficulty or some resistance because then you come up with something better. So we came up with the ex-vessel core coolability idea that I believe is more robust than even the in-vessel and so we're now with the ex-vessel coolability.

The reason that this came to that isbecause natural ex-vessel coolability cannot be assured. I don't think I need to explain that to you. You know this very well. It hasn't been possible to demonstrate that if you have a melt that is allowed to fall on the floor and you have water before or after, I don't care when you have it, you cannot demonstrate that this thing is coolable.

In Sweden, the Swedish reactors, as you know, they have also very large pools under the reactors. In fact, they put those pools there, many meters, I think it's maybe about ten meters deep.

Professor Becker suggested that they put those pools there so that the melt as it comes out, fragments and it's supposed to be coolable. Well, that creates great news with steam explosions first of all and we've done calculations of that and you find that indeed the pedestals in that case will not hold it if you had a steam explosion and even the coolability problem is not right because you have such deep pools that actually will not remain coolable and we have a problem this way.

So we have come up within this what you call the Boundary-Internal Melt Arrest and Coolability. I think I should use this for pointing, Boundary-Internal Melt Arrest and Coolability device, this BiMAC which accomplishes this purpose very well as you will see in a moment. It will accomplish the purpose of first of all allowing you to not have water there at the time that the melt comes out. That's where the measurable core is going to occur and if there is a concern about steam explosion, that will be the time with your concern about steam explosion.

The reason that it allows you to start off without having the lower drywell flooded is because the moment that water is added to BiMAC and this can be done essentially instantaneously after the melting, BiMAC is effective to operate as an impenetrable device. That is a boundary of which the melt cannot penetrate.

The concept is very similar to universal retention in the sense that we have still a boundary. We have water coolable below. Because of this as long as the thing is actually a nuclear boiling and we've demonstrated that's the case, the temperature on the other side of the still is so low that actually the fuses melt. And the size and the wall thickness of those pipes are such that so that they have significant integrity so that even a small steam explosion will be no problem to them.

Having established this robust coolability posture for this reactor ex-vessel, we won't need to be concerned about ex-vessel phenomena because of the nature of this device basically will catch anything and everything that comes down. There is no scenario dependence. It's going to come 20 percent first, 30 percent later, but you know it's not going to be 100 percent coming in all at once. But even if it did, that's fine. It's going to be all contained inside.

So really that leaves only two more things to be concerned about and that is what happens if we have some steam explosions there if for some reason it's part of the accident and we end up with deep water pools especially subcool water pools in the lower drywell. And then other one is what if we have a high pressure scenario in which the vessel failed at high pressure and gave rise to what is known as the direct containment helium.

So for this problem, we ended up with BiMAC. For this problem, we ended up with some procedure changes and some hardware changes that minimize the scenarios that gives us all the water in the lower drywell and for this one, we basically did nothing except do a fundamentals based analysis that shows that no matter what happens the ESBWR drywell in containment will not be overstressed by the direct containment heating.

So my opinion, the serious issue as far as the safety of this reactor as far as your evaluations is this one here. Does it work as we say it's going to work? The other ones, this is one percent of the whole CDF and that's another one of the whole CDF.

Actually, it turns out quite interesting from a very fundamental and from a technical point of view. So I don't know to what extent you want me to go over those, but I have them here and I will start going. But please if you feel that you want to go more, spend more time here, I'll be very happy to.

So the way that I have arranged this presentation is in the same order as in the report which I hope all of you have had with you since last August, actually since last November and I hope you had a chance to look at it. But here, I'm going to go in reverse order. I'm going to first go here and then here and then there.

All right. Just to summarize then, the severe accident threats and failure modes, direct containment heating, because in here, it's a failure of a reactor drywell. I remind you that the ABWR assumed that in this scenario would fail the drywell and that was one of the reasons that actually the NRC staff in their evaluation report, they assigned the maximum possible for conditional containment failure probability. It was because of that support failure and they did a very hypothetical analysis actually. I still don't know how they ended up with failure because it's not possible to make those reactors fail with suppression pool because of this. You will see in a moment why. So that's one issue.

The other issue is a much smaller one and that is if you don't fail catastrophically in the drywell, can you fail the liner because the liner is containment boundary and if you did, then you would have trouble. The liner, of course, will fail because of thermal effects if it fails while the drywell will fail because of pressure overstress.

Then ex-vessel explosions, the concern here is the pedestal of course along with the liner failure because of the energetics of the explosion. But here in addition, we have a new twist because of the BiMAC and we need to know if the pipes, those pipes that they put there will survive an explosion.

And finally on the basemat melt penetration, that is the, I guess, the current state-of-the-art. I don't know if you want to call it state-of-the-art, but the current approach is that if what if we can show that we're not going to penetrate the basemat melt in 24 hours maybe you're okay. That's the 24 hours rule and then maybe if we can show that actually for this reactor you can show that it will survive maybe up to 72 hours, maybe even more than 72 hours. That's all right.

But with the BiMAC, we eliminate all that because there would be no attack at all and for a BWR, this one, with a small containment, that's very good because you don't have to worry about any condensables coming in.

Therefore, we have translated the problem from sort of hypothetical analysis, basically sharpening the pencil, about how long does it take the melt to go through the process and does it go faster this way or this way and so on, all this stuff. Here we're putting a boundary that cannot be penetrated and therefore our concern is to show that what does it take to fail this boundary. So our problem is to something else, more of an engineering, more tangible and I'll show you in a moment BiMAC can be tested the full scale. So it's a much more, much better domain in which to operate on technical grounds.

By the way, I know you have heard, that we have large quantities of melt on the floor. People are going to say, I'm not going to say because I don't care to, but people will say, "We don't know. Actually it's maybe going faster this way than that way." So a big issue these days about that again from what I heard. So this is good and this is simple and very easy to apply and I believe one day I hope many reactors will use this, not only the ESBWR, very similar things, pipes and downward.

So for the BiMAC again we need to worry about burnouts, something I call burnout. The burnout can occur if the thermal loading locally or in one or more of those tubes is about the critical heat flash of the water boiling on the inside. That's one way of failing.

Another way of failing is that you have so much power going into those tubes that actually the two-phase flow actually gets water depleted. So actually you get the sense of the water coming in and the steam coming out around so in that case there's no water to create boiling.

Of course, we need to worry also about stability because we want to make sure the flow is reasonably stable going through.

And finally, we need to worry about melt impingement, melt coming out heating whatever is on top of the pipes making sure that they will not be eroding. This we call it sacrificial layer we put on the top essentially to protect the pipes.

A couple more, an illustration here, a depiction of the three failure modes and please forgive me for too many acronyms, but DCH as everybody knows, EVE is ex-vessel explosion again is well known, and BMP basemat melt penetration. By that we're referring to the melt eating up the concrete. So those are our three issues and was read and interpreted here. What it shows is that's too complicated, but mainly I want to show you this is scenario three is one percent of the CDF which is 10 to the minus 8 roughly. That is the high pressure scenario. Ninety percent of low pressure scenarios so all the high pressure scenarios there which is shown over here. We need to worry about DCH.

For all the low pressure scenarios over here, scenario one, we need to worry about DCDs. So therefore, the question arises in those scenarios, how many of them, what fraction of them, are very deep water pool and what it shows here less than one percent and that would be a deep water pool. The rest of them are either no water at all or very low water.

So in this way, this is what I meant. Those are relatively unimportant because that's one percent and that's one percent. However all of them, any accident, anything that's going to lead to large melting of the core has to be dealt with in a coolability point of view. So that's why all pervasive features in the accidents is this part here which surrounds everything. So that's why I put a lot of emphasis on that.

Here maybe this looks too busy, but I think I want to point to a few items that are important for our analysis and I have marked those with red so that I remember also not to forget something. First of all, upper drywell/lower drywell, that's our nomenclature. As far as DCH, the volumes are important of the lower drywell. That's where the mixing is occurring. It's going to lead to pressurization of the drywell. Very fundamental to BWRs and relative to high pressure scenarios and containment heating is these vents which allow these volumes to vent through the water into the wetwell.

So that when you pressurize, you're initially releasing. Remember now. We're talking about here many hundreds of minutes of speed of the steam and how is it coming out of here. Actually, it's quite phenomenal what can occur and we've done, you see a tremendously interesting gas flow particles occurring over there. So in almost no time at all, this pressurizes and the space here is totally out of scale. That's why I emphasized to tell you this is not to scale. Over here, there is a restriction because of the supporting vessel. So over here, there is like a 70 percent reduction in the flow heading.

So first, we pressurize that. Then you have to pressurize that and that behaves as a closed volume as long as the vents are not clear just like the LOCA. So if you're interested in the integrity of this thing, you have to be sure you calculate correctly vent clearing.

All right. But then once the vents open up, then the issue is whether the vent capacity of those vents can compensate for the supply energy in the upper drywell. We'll show you what that is.

All right. So as far as DCH, those are the key components and there's still another one that I want to point out here and that is again another present core well in that there is some skirts over here that they are calling refueling skirts and basically they are closing off that space. This is a metallic head of the drywell. That can become a limited component in pressure. We're showing that the force is isolated so whatever happens over here, that upper head doesn't know it because of that. It has holes basically that are communicated from here to here.

The other important thing that's crucial for an integrity point of view is that the head is immersed in a whirlpool that is a pool and the heat flies from the upper head because there is installation here into the drywell head actually is very low. It's so low that you won't even cause water to boil. So if you want to do a structural analysis of this thing, you should be doing it with a cold CAD of the upper drywell. That's very important for assessing the fragility of the drywell.

CHAIRMAN APOSTOLAKIS: What is the name of that pool above the spherical thing?

MR. THEOFANOUS: This pool over here?

CHAIRMAN APOSTOLAKIS: Yes.

MR. THEOFANOUS: Well, this pool is --

CHAIRMAN APOSTOLAKIS: It's a separate pool. It's not --

MR. THEOFANOUS: It's separate. It's actually separates the PCCS from the pools.

CHAIRMAN APOSTOLAKIS: Yes, PCCS.

MR. THEOFANOUS: It's separate from that and it is there, I guess, I don't know why that is there. It's just a reactor for the fueling pump. They want to have some space there for refueling.

About steam explosion, you're talking about this page over here and that is something like maybe seven or eight meters deep and it has about ten meters in the round which is a really big space and your concern is that there are doors and those are the hatches over here and here through which people are coming for the refueling purposes. The pedestal is made out of two and a half meters reinforced concrete and that is not just to take care of spillage. This is just because of structural consideration because the reactor is very big and very heavy. That's what defines the very robust walls. To my knowledge, those are the most robust walls that are in pressure-suppression containments.

The thing on the DCH that I forgot to mention and I do want to point out is these little horizontal lines that go like that and those are called lips and I found out. I was suggesting to people that we want to put lips there because we will most likely, this DCH most likely is going to fail the liner here just by splashing about. If it hits, it would very likely fail. So I didn't want to hear a communication from the back liner space from here up to these parts of the container boundary.

But then I found out and we checks that this is part of a normal practice. Every so often, they make lips from the liner that are going to the concrete sort of like compartmentalizing the liner. So you could very well, if you failed the liner over here, but that doesn't communicate with the back liner space over here. So in addition to having those anchors into the concrete that hold the liner, you also have those lips.

Going back to then steam explosion as you will see, I don't believe there's any problem with two and a half meter reinforced concrete for steam explosions for the pedestal, although if you do a real humongous steam explosion like the ones that we can actually compute, we find out that we are getting there even to the upgraded. We also did structural vibrations and we found out that although normally people thought the pedestal would take about 100 or 150 kilo-Pascal seconds, it turns out we're showing even 600 kilo-Pascal seconds almost four or five times that with these walls you will begin to just reach a seepage. Also it's very robust from an explosion point of view.

But it is initially the hatches which are likely to fail if they are overloaded and of course, there is the issue of the BiMAC that we want to make sure that we don't run above 600 kilo-Pascal seconds.

CHAIRMAN APOSTOLAKIS: I don't quite see where the BiMAC is.

MR. THEOFANOUS: You'll see that in a moment. I'm coming to that. That's the third item. I just finished with the explosion. So the third item is the basemat melt penetration which we said we want to protect with the BiMAC and I'll come to the next one to show you the design, but the BiMAC fits right in here covering the whole space and the last point to make here is that with BiMAC working plus the PCCS we have no possibility of long term failure of this. And that's very comforting.

So here is the BiMAC, and the concept basically is make a jacket with pipes and those pipes are lined up with some intonation. It is largely a two dimensional point. We have chosen this to be ten degrees and that ten degrees comes from the idea that a ten degree is the critical heat flux because remember now these pipes are going to heated from above sort of like that.

All right. Now as you increase from there as you go to a different level, of course, you make it possible for the evaporation to go at higher velocities and that creates more agitation and most important, we see a wetting of the wall as the vapor sluices by and when that happens, you get an increase of the heat flux and that increases pretty steeply for about up to about 15 degrees or so. Then it sort of levels out a little bit and therefore you go to a very high orientation when it goes very high. So our interest here is to try to cut that. So that's why it's not five, ten degrees. Then those pipes then come, here you have a vertical segment. In this way, then we can protect the floor. We can protect the walls. We protect even the sumps.

The other consideration here is to making sure that there is enough capacity inside of this dish, if you like, that will catch not only one core but more than one core. We can catch four cores.

MEMBER WALLIS: This is made of concrete, this brownish stuff or is this --

MR. THEOFANOUS: This is the normal concrete. This is something that's in there.

MEMBER WALLIS: What's this?

MR. THEOFANOUS: This other stuff here, that is additional concrete. We call it sacrificial material. The one on the top especially will be made out of refractory material like zirconia that would resist impingement of the melt. From the point of view of, let's say, having a melt on the top of it, I don't care whether there is any concrete or not. I don't care what concrete is there, but we were concerned about possible melt coming out in some velocity and coming and hitting it and penetrating those pipes. Of course, if you penetrate the pipes at that point, you're --

MEMBER WALLIS: Again you say parallel

pipes. I presume it's not a cone one there.

MR. THEOFANOUS: It's a cone that is a two dimensional cone. It's like what you see here is a cut through this way.

MEMBER WALLIS: Okay, but in the other direction --

MR. THEOFANOUS: The other one is straight.

MEMBER WALLIS: Okay.

MR. THEOFANOUS: Okay. So I'll come to a --

MEMBER WALLIS: It's almost like a valve.

MR. THEOFANOUS: Yes, like that. Now it's very interesting to point out something that's a little harder to conceive, but I think I can explain it that if you make this cut that is shown over here is through a diameter of the drywall that is normal to our view. Now if you begin to cut now with additional slices going away or forward from there, then you'll find that this dimension is going to get smaller, smaller and smaller.

MEMBER MAYNARD: The angle would stay the same.

MR. THEOFANOUS: The angle will stay the same. So that's basically going to get smaller. So near the end, you're going to end up with channels that are very short in this direction, in the incline direction and long in the vertical direction. All right. That's important and I'll come back to that. Now it's important from the point of view of thermal loading. I'll explain something that's quite interesting from a thermal loading point of view.

That's that. That's one called boundary internal. We are bounding inside. I personally believe that, I believe for a long time, that you can have a lot of core on a floor like this like an inner reactor on the concrete with lots of water in the tub and I think eventually it will become cooler.

MEMBER WALLIS: Now this comes out and floods from the top as well.

MR. THEOFANOUS: I'll explain that in a moment, but let me finish my thought here which is eventually it will be cooled, but we can't demonstrate that. That's the problem. So it's very possible that this BiMAC never comes into play even if you --

MEMBER WALLIS: When does it switch on? Do you wait --

MR. THEOFANOUS: I'll come to that.

MEMBER WALLIS: Do you wait until you --

MR. THEOFANOUS: You're very impatient.

You're very impatient. Just wait a minute.

MEMBER WALLIS: Well, you've spoken all the time. I can speak --

MR. THEOFANOUS: You can ask a question if you like, but don't talk to me for the future of what's coming up.

CHAIRMAN APOSTOLAKIS: Can you point to the certainly BiMAC itself? The BiMAC consists of what?

MR. THEOFANOUS: The BiMAC consists of this dish and then you're right that there is an integral piece of that which is the lines that are coming from GDCS, the lines which are coming in and I'll come to that in a moment. I want to give you sort of a global view, not too much of the technical details because I think more detail plots later I'll show you.

I'd also like to answer this very question. What I said before, BiMAC works right away and the reason is that it is connected to the GDCS. So the moment you turn on the valve, that valve supplies this central part that goes that way. So it's filled up right away and the flow is running out of all of those pipes which means that it's essentially it's immediately effective for cooling.

However at some point the GDCS is going to run out of water and especially --

MEMBER WALLIS: I'm not quite sure of that. We have an event. We haven't gone through the vessel yet. Do you switch this thing on before?

MR. THEOFANOUS: No, no. We said --

MEMBER WALLIS: When do you switch it on?

MR. THEOFANOUS: I'll get to it.

MEMBER WALLIS: No, I'm with you. I want to know what's happening.

MR. THEOFANOUS: I said before but you weren't thinking. You were a little bit paying attention to something else.

MEMBER WALLIS: Okay.

MR. THEOFANOUS: I said earlier we are switching it on after the initial core of the melt. We don't want to have water there when the first core occurs because it will give us steam explosions.

MEMBER WALLIS: The first core. That's right.

MR. THEOFANOUS: Okay. So we're switching it on after the first core and then after that happens, then we have plenty of water there and it continues.

MEMBER ARMIJO: When do you know that you actually have melt on the floor? How do you know?

MR. THEOFANOUS: By temperatures. Again we'll come to those issues in a moment. I think now let's first just get -- make sure that we understand that and then we'll find some of those.

MEMBER WALLIS: What is on the lid? What is the lid?

MR. THEOFANOUS: Yes. If you let me explain, I was trying to get there.

CHAIRMAN APOSTOLAKIS: Okay. Let him talk.

MR. THEOFANOUS: So we want this to be very basic in the concrete. I got into this stuff because I was telling you that this may never even come into play even if you have a problem. Okay. It's better than here. So what we have here, we have a grate with support poles which are not illustrated here which are basically holding a plate also. Actually you don't know there's anything there. It's just a steel plate that is thin.

It's like two millimeters thick on the steel plate and the reason why it's thin is because I want it. That's not an important part of the consideration but I wanted it. It is a high pressure melt injection, I have a melt jet coming out at high velocity. I want this to melt right away rather than splattering. I want to melt locally right away and then the melt is going to flow right in here and I say I think most of it is going to be captured, because there is a high velocity steam. By the time, you have it reach here, this high velocity steam has expanded to about 20 times the area.

Therefore, that stagnation pressure holds the plate down and therefore, this plate is quite resilient as long as you have enough support for it and it will just stay there and the melt will catch. Some melts will come out. That is discussed in the report. I don't want to take time for this now. So small amounts will come out, but it's good to have it there.

So now, I'm also showing that the operation of this initially will be with water coming in from here and then going out from the vertical pipes, all the vertical pipes. Okay. Now later on when the water finishes coming in here, then we have other downcomers which are, now this time the pool is already filled up and our water is coming in from those channels that are not heated or from the downcomers.

So I will talk about assessing elements

and how again we say it's very important for this and to inquire in this report the very high level ability for switching on the water coming in, high level ability also for not switching it wrongly on. All right. It was not our job to design completely the sensing elements, however, just talking with designers we have some ideas we can use, for example, thermocouples that are embedded in here so the moment that something came in, you know it's high temperature.

You can use also spring actuated nitrogen bottles which hold some pressure so that when the temperature goes high, some detector melts and then opens up and opens up the valve. I like basically to make this spositively activated based on very high temperatures in here.

MEMBER WALLIS: And the brown stuff there is?

MR. THEOFANOUS: The sacrificial material like I said before. The important part is at the top. The top should be something that is very resistant like a refractory material, zirconia, something like that and it would be like 20 centimeters. You don't need very much there.

All right. So now it is from the point of view of evaluating. I'm now going to the three topics and again please use your prerogative as a committee. You can tell me that there's too much detail here. Let's go to BiMAC. But my idea is to at least touch on these issues to then finally come to BiMAC.

So the direct containment heating, I'm going to cover a number of items. One item is containers depressurization. Is it possible you have sitting there a vessel sitting there all buttoned up with very high temperatures for such a long time. We asked that question first. Then the parameter range covered, also whole range parameters and results. Then the thermal loads. And that finishes the catastrophic part.

Then over here is thermal loads to liner. And then we want to compare to fragility. The fragility we have nothing with do with the fragility. This was taken from one other chapter of 33201 and summary of bounding approaches, we'll conclude, just like finish here.

First, this potential for this container depressurization, I should remind that you for PWRs the DCH depressurizes.

So I asked the question initially after can this happen and there are three possibilities.

There is the possibility of the isolation condenser, the pipe that goes into the isolation condenser. There is the, here it explains in detail, main steam line and then SRV that hangs off from there and so we have three places.

But actually the one that is important is this because here is closed first and it operates continuously and therefore you get especially into high temperature or element in the element. You get hydrogen produced and now you have also good thermal conductivity material that is found out here.

The other thing to point out is this is high pressure source steam and hydrogen can carry all the heat. That's why you saw exactly that it's not convection in the steam environment. Normally, you wouldn't have expected it. It was in fact it's high pressure steam and high density, so it can carry all the heat around.

So the question is will that fail and we took the typical materials for the construction materials and what is showing here is showing that this is the count of the material strength and this is the temperature and here is the main steam line, here is the isolation condenser and here is the SRV. What that means is that the main steam line should be between 1,000 and 100 degrees to fail, the isolation projection in this range and the SRV in this range. The SRV is made much more substantial because it has to take loads and that's why it has more strength. That's why it can take higher temperature.

So the question now basically is can you actually achieve this kind of temperature in the MSL which as I showed you the MSL is heated by the flow going to the SLV. Just happens the MSL was a pipe, a thinner one, so that's why it's here. The typical core transient, it doesn't really depend on what core you use. You will find that you get a lot of oxidation and get a lot of snowballing effect and you get temperatures of 3,000 degrees for two and a half hours. So all you have there is like a quicken path with 3,000 degrees over here. Gas is naturally conducting.

And you ask the question will you ever reach 1,000 degrees? I think you will. But I didn't want to just arrive just to that and say okay, we don't have DCH problem. It was kind of fun to work through the dynamics of the DCH as well. So that's what we've done. That's what I want to show you how that works.

First point because I've seen analysis of people not so BWRs. Several of my old NRC friends wanted to see a real good BWR, DCH analysis. So I think this is going to do that. But I've seen people that have done interpretations of experiments as well as PWR calculations trying to get the fallout and then they average out over the whole cross-section area of the space which is fine.

Actually you see that we've done CRD simulations and I think I'll get into a problem here if somebody knows how to do that. You find out that you get a supersonic jet out here. It's something like 600 meters per second, this fantastic speed you get and this jet comes and hits the bottom floor and is diverted and becomes a wall jet around the floor and then it's diverted again and becomes a vertical jet with hundreds of meters per second out here. If you average it out, it just like a fizzle, well not quite a fizzle but it is much lower of course because this is a big area.

So I believe that this as well as any other reactor that I have done for PWR before this process here is tremendously intense. In fact, I was so curious about this that I even did a few experiments in my lab with a scale to that. We did some experiments and it's an amazing force. So there's very little doubt in my mind that we really have a high pressure melt ejection unit right here.

And what the other fundamental physics here is that you have a liquid mass. Liquid masses are microscopic in inertia. So therefore it is not so easy to accelerate those masses and get them out before they fragment and mix with steam. So the reason we have this very fine fermentation is because of the melting velocity and the instabilities which created basically an atomizing mechanism that is very fine.

MEMBER WALLIS: Why does this high velocity, very hot jet, why does it get diverted, not simply drill a hole?

MR. THEOFANOUS: Why does it do what?

MEMBER WALLIS: The high velocity jets can drill holes as well as get splashed. They can drill holes in things. Why doesn't it drill a hole right through the base?

MR. THEOFANOUS: Because like we're saying, we're protecting that with the refractory material.

MEMBER WALLIS: Oh. Well --

MR. THEOFANOUS: Before you can actually, there's five meters of concrete on the floor and it's on top --

MEMBER WALLIS: Five meters, that stuff is five meters thick, that brown stuff.

MR. THEOFANOUS: No, but it's all connected together. It is sitting on the top of the --

MEMBER WALLIS: I would think it would destroy some of your tubes.

MR. THEOFANOUS: Well, you might think so, but --

MEMBER WALLIS: Well, I'm just asking. Does it destroy?

(Several speaking at once.)

MR. THEOFANOUS: No, I'll just tell you now. It doesn't destroy the tube.

MEMBER WALLIS: You just told us it had tremendous force and all this stuff. So I would think you --

MR. THEOFANOUS: Yes, we know exactly what the force is. We know. We've --

MEMBER WALLIS: So you have analyzed the survival of the tubes.

MR. THEOFANOUS: Sure. In the report. In the report, you will find the stagnation pressures for the --

MEMBER WALLIS: You will find all that stuff. Okay.

MR. THEOFANOUS: So now the problem we want to solve here is therefore steam coming out at high velocities, mixing up very intensely reducing very fine automatization of the melt and especially it is zirconia that's there and oxidating it and releasing the oxidation energy from the point of view of most gas coming out. It doesn't make much difference because you have one more hydrogen or more steam, the same thing so it's all there. We have another containment here. So it doesn't really matter whether it's hydrogen or steam.

However, there is extra energy that is in this initial oxidation and that heats up the gases and that's important. Before the gases go through this operational pool, the temperature is very important because that really generates the peak of the pressure and there you need to account correctly for all that.

So we have them not coming out. Then steam after that. Automatization, oxidation fine scale. The stuff is blown out into the space over here and there it separates some of the bigger pieces. They fall off. The velocities are very low by the way out here, very low. But this volume is pressurizing now quickly and will continue to pressurize like as if it was a closed volume until the vent's clear. That is a process that can take like a second. So it's very intricate and you want to calculate that correctly.

Now I want to contrast that a little bit with what we did for issue resolution for pressurized water reactors. This was our probabilistic framework that we used and you'll see here that there is a lot of detail like there is amassed how much O_2 you have or how much zirconia and how much was steel and then how you get pressurization as a result of these compositions and then something we call the coherence (PH) ratio which has to do with how much of the steam is in to see how much of the melt here in this process and all this was happening in the closed because there was a lot of static containment. It was in a closed volume. It couldn't go anywhere. So in fact, in this case, the dynamics were not so important. It was what's important was the maximum pressure and that's why also Marty Pilch who worked with me together to do this serious problem. He used what's called a two cell equilibrium model which basically does the same thing that my model did except that one was just like an equilibrium thermal dynamics. So take that and put it equal and put it equal.

So here for this reactor, it's not enough to get the final pressure because you have an optimum volume pretty sure we can -- So we want to get the dynamics so the full -- is needed. So we use the same. We call it convection limited containment heating (CLCH). We use that same model but now in a full transient model. The model assumes basically that the steam and the melt come to what -- the perimeter at some rate in which the melt is being carried out as fine particles to go out. So that defines the rates of contact, the rate of containment and the steam going down. Okay?

Then basically that's what we did and the reason I put this up here because I want to show you that the evaluation for PWRs, thanks to the presence of this suppression pool and the venting from that volume from the drywell to the wetwell actually is totally insensitive to essentially all that stuff. So you can assume the whole mass and even more, almost anything you can do, you can not overpressurize this area.

So what you've done here, that's new, is you've extended the model to make it transient and then we coupled to event clearing model and then each one of those models were verified in the transient --

And here is to illustrate for you the facilities which were used, the data we used, came from. This is IET series. It's called integral effect tests that were run in counterpart, two series (PH) SND at 1/10th scale. That's the South Sea facility at 1/10th scale and then at 1/20th scale, at I think it's called core exit facility -- used real materials and they used -- Pretty significant sized experiments. That's what we used every time for very fine my model and Marty Pilch's model and we could get done the job for the PWRs.

I'm using the same data here but now also paying a lot of attention to the transient itself and I'll show you in a moment the results.

MEMBER WALLIS: I have no idea what you're modeling here.

MR. THEOFANOUS: I'm sorry.

MEMBER WALLIS: I have no idea what you're modeling. What is this supposed to be modeling?

MR. THEOFANOUS: What the experiment is modeling?

MEMBER WALLIS: Yes.

MR. THEOFANOUS: It is modeling the process I described to you.

MEMBER WALLIS: It's modeling the entire containment with the venting and everything.

MR. THEOFANOUS: No. I said this is for PWRs. Okay. This is for PWRs, pressurized water reactors.

MEMBER WALLIS: So what is it modeling then?

MR. THEOFANOUS: So it's modeling their containment heating processes in what is dry container which means there is a reactor, there is a reactor cavity, there is a --

MEMBER WALLIS: You're squirting something into this containment and --

MR. THEOFANOUS: They are squirting something into the cavity of a PWR and then you have a containment which is this one here which is like what is dry containment to find how much pressure you get. In this case for PWR, you're also going to know how much hydrogen you get and you're going to know whether that hydrogen is going to combust or not. So it was a real challenge here to find also the hydrogen produced and the combustible hydrogen because that evolved into the final pressure here.

Now in our case, we are interested in the -- And CLCH model was found to work as well actually in telling the hydrogen and final pressure and everything. Here we are interested in reactor containments. So some of those tests were done with nitrogen only in the large volume here. So we used those obviously because those are the ones that are relevant for the present comparison. That's that. The other one -- So that's for the DCH phenomenon itself.

Over here, we have the vent clearing, what I was telling you before, and those are the PSTF experiments. Those were actually done when I was a little child. A long time ago. I remember those tests. Actually I've been inside those facilities at the time I was a consultant and we were looking over those tests. I was sitting on the other side of the test and those are full scale actually. Those are full scale and that full scale is the same full scale as we have in the ESBWR. Actually it's exactly the same.

MEMBER DENNING: But that's the easy part of the problem. Right? That's just acceleration of the slug and it's just verified how long it takes to accelerate.

MR. THEOFANOUS: Yes. But you'd better do it though because -- So I'll show you in a moment.

It's a very interesting dynamic because of that. So what happens here you get a supply of vapor going into some of the models of drywell. That pressurizes and that pushes through the down carbon and through the vents and pushes it right out and pressurizes this and this. So that's the dynamics we're interested in doing.

So I want to show the verification of the reports and they're coming together to do the full DCH. Here is an example of the IET DCH test model experiments. This is typical comparison with the vent clearing. The vent clearing, you like to know you catch the peak and also the time of the clearing. In the report, you'll find more details about both of those things. It's interesting to point out that in this test here and this is for the significant one notice that we are much even in the long term and the reason is that there was such a big facility here the velocities were negligible. If you look at the Argun test, you find that the experimental data, they show the decline even in times like this and the reason is you have heat losses which of course you don't care about.

All right. So now the dynamics, there are three regimes that I've identified for quantifying the log. So we just go on and run some calculations and show further pressure and velocity. We wouldn't understand what's going on and what drives it. So what drives it here is that Regime I you hold hypothetical because it is a very humongous area of failure of the lower head. There is something around one meter in diameter all at once forming. If that was to occur, you'd have pressurization that is so strong because of DCH that actually the pressure in the lower drywell which is this exceeds the pressure in the upper drywell very significantly just because of that restriction I was telling you about.

All right. So we form a structure first and then it reaches a maximum, but then of course as it goes to high enough pressures, it is able to vent faster. So you have a decrease. Then it cuts --with it. So from that point on, the pressure is essentially made the same and then at that point, it finishes the blowdown. At this point again, this cools and the wetwell gradually arises as the contents of the drywell atmosphere vents into the water.

MEMBER DENNING: Those are results of your analytic tool?

MR. THEOFANOUS: Yes.

MEMBER DENNING: And in this case you have basically two separated volumes.

MR. THEOFANOUS: Yes.

MEMBER DENNING: Whereas in the PWR, you had only one line.

MR. THEOFANOUS: One and it wasn't even passing. The PWR, it was like we only looked at the final result.

All right. So that's hypothetical. That's Regime I. That's a very extreme regime, but even that one doesn't fail. By the way, you'll see in a moment that the containment is beginning to be challenged around this pressure. So around 11 to 12 bar.

MEMBER DENNING: Is that what the fragility is?

MR. THEOFANOUS: Yes, that's the fragility for the drywell. I'll show you in a moment. Then the Regime I is if you took an extreme of the case we have used for a creep rupture in pressurized water reactor the one we had during DCH and for that only, we used 0.55 meters in diameter. So we have given a probability distribution of the possible sizes. Where 11 narrow I was reminding myself the other day is a narrow distribution but the very upper outside end of that was 0.55.

This calculation here was around 0.5. I wanted to be exactly literally correct when I said we took the upper limits. I just had the calculation around yesterday of 0.55 and of course, that's a very slight difference from that.

So in effect, what the source here is that this initial difference in pressure between the lower and upper drywell is limited to a very short time. Instead of a peak here, you get an inflection point. They join together. Again there is a peak and there is some panning order, finally catches up here with the wetwell. Eventually from there, it goes out like that.

I want to tell you that it takes something like about 30 seconds, 40 seconds, to do the full blowdown, but the main part is during the time that you put in the melt out and I'll show you how one is to do that and the shorter you make that melted premium time the more big piles you make over here because it happened before the event is cleared. The longer you make the melted premium time the more you're spreading out the energy into the steam. So now from one point of view, that helps you oxidize more. It helps you more contact, more energy comes out, but on the other hand, the cooling spreads it out brings in this suppression pool after the clearing. So from one hand, that helps on one hand. On the other, no matter what you do you can't get into -- So that is Regime II. That's the upper end of the category range for PWRs and those would be PWRs. The reason we did that by the way is because some PWRs have no penetration to the lower head. That means it will suffer from creep rupture and then we have to know how big the area is. In this reactor as well as in some other PWRs where there are penetrations you essentially never expect to have a creep rupture scenario.

And then finally Regime III is the most likely scene for a boiling water reactor and that is if one or more of the penetrations fail and it doesn't really matter whether it's one or two or three or four because if you fail more penetrations then the melt comes out sooner. It doesn't not bleed so much so that the final area is not so different from having one and you let it -- and in the process of melt coming through the hole is un plated, un plated, un plated, and eventually comes out to something like in this case about 30 centimeters. That is a huge hole.

So therefore the relevant area for getting steam out is 30 centimeters diameter hole. In that case, Regime III as you see the dynamics are much more benign and this is the steam that is falling out the melt. That is again a creep rupture-like scenario like the one I showed you.

So here is the coverage. We've done 50, 100, 300 cones. Three hundred cones is basically more than what you have there even if you accounted for everything. The diameters, these are typical of creep rupture. These are smaller. I'm sorry. Penetration failure. These are smaller than those because a smaller amount of mass therefore less oblation. Then 0.5 is for the creep rupture I was telling you.

The temperature inside the vessel was taken to was taken to be 100, 150, 100. Actually, the higher the temperature is the less density of the steam inside and therefore the less potential for oxidizing. So actually you make it more severe by using a lower temperature and that's why you use lower temperature.

The t_m needs some explanation. That is the --

MEMBER WALLIS: What is the temperature of the core area?

MR. THEOFANOUS: The core is around 2500 degrees, maybe higher.

MR. THEOFANOUS: The t_m is what you call the mixing time or melted varying time and that is we have this formulation for calculating that in the pressurized water reactor case and use the same one because basically there is steam and -- like things going out but we played what we call metrics and as I told you that's a matter of use. But typically for these kinds of situations we have about seven to ten seconds of time for this to come out.

If you make this melt time, of course, given an area if blowdown of the steam is fixed by the area and the pressure so now if you said that I'm going to take this t_m to be very short, what that means is that you're going to allow a lot of the steam in the area up high during which the melt is coming out basically to be not useable because it -- and there's nothing more to oxidize. So by making that too short, you're making higher the defaults, you try to make higher the defaults, however you are -- That's why we call it convection conductivity. It's really limited by that process. But we've done 3.6, ten seconds, so a whole range of different choices here.

And here are the results. By the way an important parameter that we call the DCH scale expresses that coherence between the melt coming out and the steam coming out. Those are two characteristic times for that process. This ratio, it's very important because when that ratio is less than one, as I said before, the process is still limited and it's less than what it is the elastic pressure again. So for example in a dry container even, if that's very small you get much more pressure than compared to if it is but one. So actually in a dry container, if you plotted the pressure increase versus this coherent ratio you find out another steep increase up to one and up to one should have straight up.

So what you see here is what we have and our cases are anywhere from as low as 0.104 to as high as 1.3. So we have covered the whole spectrum of likely contacts between the steam and the -- I should point out the pressures however. The first peak is very modest in relation to the fragility. The second peak is also very modest. As you're going to this, these are creep rupture scenarios you get about six bar. Then the temperatures, I'll show you in a moment how the temperature does. It looks like it goes up and then it goes down and eventually settles in about a minute settle to some value and that value is around one thousand degrees.

MEMBER DENNING: You're not showing that first kind that you first showed us because that's not considered credible.

MR. THEOFANOUS: I wanted to do that because I wanted to provide a backdrop against which you can see where the conservative case is and then the more likely case is. So we also did run outside of the report outside of Chapter 21 additional sensitivities about condensation and dust cooling, oxidation efficiency composition and drywell atmosphere and so on and basically same results. So here then putting it together, here is the upper bound is six bars I was showing you before, upper bound of the loading that you could have and it really doesn't decept the fragility. I don't want to get into any games about saying so much of that is like this and so much of that this. Just I used here the complimentary cumulative distribution. So everything is below that.

Then for the fragility which is as I said we got from another chapter of the VDOT report is initially here. You see that for the 50 percent values about 16 bars. This value here around 11 or 12 is running two percent only. Over here is 10^{-5}. So it's really just there's no intersection whatsoever. So that's the story for DCH and I don't know if I want to belabor that anymore. This is a conservative area as it is as in the PWR case the creep rupture is on the upper limit of the size and upper bound of available materials participating and no new section at all.

The temperatures now, coming to temperatures, here is a typical behavior we see. We see a very high pressure pulse -- temperature pulse in the lower drywell. Of course, it makes sense because not only have you got 2,000 degrees in the melt but now you get the oxidation area and you have a tremendous energy machine for using there. So you can reach another 1,000 degrees when you cover it.

Now why does it go so steeply down is because after the melt gets out of there then basically it washes out with the cool steam and hydrogen that come out from the vessel expanding and cooling down. So that's the issue I intend to show now. But keep in mind this temperature on the 1,000 degrees because that's really a benchmark against which to say now if I have this for a few minutes on the upper drywell what will happen with the liner and the liner started sagging. Obviously if the liner had no anchors, you would see the liner sort of falling off by its own weight because it's really that one that's stripping off.

However, in the case of which we are covered so well by those anchors, the way that has to be self supported for each, let's say, cell, that is so small that it just doesn't do anything. In fact creep helps us because it helps relieve the stresses so there is no cracking.

MEMBER ARMIJO: Why doesn't it buckle and pull away?

MR. THEOFANOUS: No, it will do some buckling. In fact, in the report, I didn't know if I had time here, but in the report you'll find pictures in which you see the full buckle. It makes like a wavy structure and that's why I'm saying it helps you because it can creep without peering, without creating cracks because of the high temperature. And then again to mention the lips again on the -- We make no claim by the way for wire integrity in the lower drywell not in light of these temperatures I wouldn't and not in light of the fact that there's all kinds of melts flashing all over the place.

Ex-Vessel Explosions and BiMAC pipe crushing and the pedestal failure, what we're saying here is that we are saying that if we had a deep pool and if we had pools of melt that are tens per second which can't be excluded, you know, people usually will use and I've seen people use tens of kilograms per second and rarely you see hundreds of kilograms per second, but this is very heavy material. If you have a core there, who is going to tell you you're not going to get a few hundreds at least.

So we used the 700 kilograms per second in our calculations and we found that in doing the impulses on the form that it can be significant. With these kinds of pools, we find that because the pedestal is quite far away and because especially shower pools can vent (PH) the energy we find that the impulses are rather low.

The impulses by the way are the figure here because these are millisecond scale pressure pulses which show the detail of the pulse, the detail of the pressure transient, is not important but rather the integral on the code. So using impulses to measure explosive release energy and then we use the impulse to measure fragility.

MEMBER WALLIS: Now in the PRAs it says that the probability of an EVE is zero for depths less than 0.7 meters. Then it becomes one when you get up to 1.5.

MR. THEOFANOUS: Where are you now?

MEMBER WALLIS: I'm reading Section 8.3-4. The notes from the PRA that we're reviewing here.

MR. THEOFANOUS: From the PRA.

MEMBER WALLIS: It says that the probability of an EVE is insignificant for water levels less than -- Is this something you did or something they did?

MR. THEOFANOUS: The rupture scenario --

MEMBER WALLIS: It says that when water up to here you have no EVE and when you have water up to here, it's a probability of one.

MR. THEOFANOUS: He did that.

MEMBER WALLIS: I'm just wondering. Can you really predict with that precision that nothing will happen when it's up to here and it's inevitable when it's up to here? Can you really predict with that precision?

MR. WACHOWIAK: This is Rick Wachowiak from General Electric. That's a calculational tool if you will. What we're saying is when it's --

MEMBER WALLIS: It's not a modeling of the physics.

MR. WACHOWIAK: When it's below, what Theo is going to show you in a minute is when it's below the lower threshold there is no way that we're going to have a steam explosion that's going to affect any of the structures or any of the equipment. When we get to the deeper subcooled pools what he's saying is that we can't rule out that there may be some damage. So when we did the calculation --

MEMBER WALLIS: You took it as one.

MR. WACHOWIAK: -- we said when it's high we assume that. We'll just take the worst case.

MR. THEOFANOUS: No, he's not asking that.

MEMBER WALLIS: So he has to --

MR. THEOFANOUS: He's asking how do you know that what fraction of scenarios are for shallow pools, what fractions are for --

MEMBER WALLIS: I'm also asking how well can you really say that it's zero for a certain height and then it suddenly becomes one.

MR. WACHOWIAK: And what I think he's going to show you is that even with the one meter or two meter that it really shouldn't be one. It should be --

MEMBER WALLIS: It's very unlikely. He's going to show it.

MR. WACHOWIAK: -- some small fraction.

MEMBER WALLIS: So we have to listen to them all.

MR. WACHOWIAK: Yes.

MR. THEOFANOUS: Unfortunately.

MEMBER WALLIS: Okay. That's all right. You'll get to it.

MR. WACHOWIAK: It's just a calculational tool that we use.

MR. THEOFANOUS: I thought you were asking about the fraction of scenarios that --

MEMBER WALLIS: No, I was asking about the probability of an EVE depending on pool depth.

MR. THEOFANOUS: Oh. Then let's go on.

MEMBER WALLIS: You're going to get to that? Okay.

MR. THEOFANOUS: I'll get to that. All right. So what you said is that there was a -- prohibiting information of such pool but design changes -- they really are. So --

MEMBER WALLIS: So you mustn't switch it on too soon.

MR. THEOFANOUS: Yes. As usual.

MEMBER WALLIS: All right.

MR. THEOFANOUS: I don't have it here, but I put that --

MEMBER WALLIS: So more water isn't necessarily better. It could be worse.

MR. THEOFANOUS: Of course. That's why I don't want to have water there.

MEMBER WALLIS: Not yet. Not until you need it.

MR. THEOFANOUS: And I don't need the water there when the -- in the reactor vessel. Now what we mean by prohibiting, you have to prohibit that, just make it less likely for having water there, that means that there was a GDCS overflow for example if we had let it when revising the original design it would basically almost virtually guarantee you're going to lots of water down there.

There was another one that would allow overflow the suppression pool which again would almost guarantee that you're going to get into some flooding situation. That was taken care of. So that's what we mean by containment layouts and systems and then in addition to that as I explained already in the case of BiMAC we want to make sure that we require the reliability of, I don't know, the reliability of 10^{-3} for failing to supply the water when needed and the same reliability of 10^{-3} for supplying the water too early. So that's a systems question. So we are going to get down to a shouting match about how we're going to assure this 10^{-3} but that's a systems question which we believe is more properly a problem for the COS stage in the license.

According to bounding estimates and impulses the conclusion is here. Fragility is the additional margin even for subpooling. So here the real picture, that's the basemat. There is a BiMAC, basically a concrete structure with pipes and with some cover of -- on the top of it and there on the floor, there is the grating and these are the two and a half meters thick pedestal wall. These are the hatches I mentioned before. So if you want to know why for example we keep that value for about two meters it will be lineated again what we foresee the deep pool or fire pool it's because if it was more than about two meters above this floor it would be exposing the hatch door to the explosion. So the issue here is one in which we have differing levels of water up here and that comes out at about ten (PH) ton per second.

What kind of pulses here can I get here and at the BiMAR? That's the question. Then will the structure survive this pulse? So already I mentioned the release rate and we did calculations for the one, two and five meter deep pools. We considered such a rate in subpool water and what we're finding is at the floor it's about 100 kilo Pascal seconds pulse up here if some cooled pool. If we have saturated water pool, we do nothing. And then, for the side walls because of the distance and because of the venting you get about 40 to 50 kilowatts Pascal seconds, but also in the fragility mode.

Now this is new. This is -- that these actually DYNA3D I think it's called -- is the commercial version which is operating for commercial purposes. This is something that's used for national security issues and of course is exercised a lot with high explosives. Now high explosives may give you assorted pulses, however, most of these is for cracking purposes. However, for our purposes here, one or two millisecond pressure pulses are also pretty steep. So we believe that's very appropriate in terms of the natural frequency structures. So that would be if there's a real disaster these days.

And I referenced in the Chapter 21, I referenced a rather extensive document when this part was published from Livermore and we tried a lot of compiled data of this --

MEMBER WALLIS: There was just a one shoot bang or does it bang and then bang again? When you're pouring the stuff into the pool, you have an explosion and everything comes together again. You're still putting stuff in. Does it explode again? Several times?

MR. THEOFANOUS: Yes. Sure. That is one of the issues that arises if you have very deep pools.

MEMBER WALLIS: Right.

MR. THEOFANOUS: That's why I don't want to say much about very deep pools. That's why I tried to stay away from deep pools because if I have a one meter pool and I have an explosion in there and the water goes all over the place, you're not going to have a pool anymore.

MEMBER WALLIS: Well, it falls back down again.

MR. THEOFANOUS: Yeah, but how long will it take for the water pressure for the --

So the calculations actually were very detailed with millions of notes and a very detailed representation of the -- By the way, those are symmetry planes and that means in a symmetry plane the thing is not allowed to move normally, but it's free to move this way and a very detailed presentation of all the rebar, the concrete, the -- bar, the -- bar, the mercury bar, everything is there in these calculations.

And here is actually a very interesting movies to show how the -- Of course, that's highly exaggerated. This is the 600 kilos Pascal second welding (PH) that we put into this loading as well and what happens in this case is you begin to have -- This is illustrated here by the yielding of the rebar and by the crashing of the concrete which is shown by this red area. So basically in the area where the concrete is, you crack it and the rebar yields and you have failing. It takes that kind of energy to be put in to create failure.

This is represented schematically here. We've done calculations with the obstacles here, here and here and there was no failure. Over here is what you just saw, some failure. So I just draw just schematically. That's why this dotted line, some kind of a cumulative salable probability that starts arising between here and here.

As I mentioned before, what was wrong before about failures of those structures was actually a paper that I did many years ago. At that time, we considered one and a half meters concrete with rebar and that was failing right around here, at around 100, 150 kilos Pascal seconds. Because of this paper, I think most people, you go out there and you ask people that know about this problem how much does it take to fail the model within 150 kilo Pascal seconds. So actually we were very pleasantly, we were anticipating some increase but that is a very significant decrease in fragility because of the size and the concrete.

Nothing special on the concrete by the way. This is just a normal 5,000 psi concrete. You can get that. If you have 10,000 psi concrete, it's going to be even better.

MEMBER DENNING: On the DYNA3D when you run that analysis, do you actually put in, you don't put in just the kilo Pascal seconds. You put in a certain --

MR. THEOFANOUS: The pulse, yes.

MEMBER DENNING: The pulse, right.

MR. THEOFANOUS: Any report you'll see all kinds of pulses. For example, it will be like twice the maximum pressure, half of the width of the pulse. You'll see a pulse here in the report. So what you are showing here then is that for the pedestal in the report you will find a number of compilations that will show you get in the report only about 100 kilo Pascal seconds. So it's a huge margin. I believe when we have pools like that, one, two meter pools you cannot fail the pedestal by a --

Because of what Graham was saying before, I don't want to say to defend an eight meter pool and what happens with that. So therefore we decided we don't want to have pools like that and we managed to do this by not flooding into --

MEMBER WALLIS: Theo, you have this pool and you have an explosion in it. Is the explosion in the middle of the pool or is it near the wall? Doesn't it make a difference where it is?

MR. THEOFANOUS: Of course.

MEMBER WALLIS: Because it attenuates there.

MR. THEOFANOUS: Yes. Of course it makes some difference.

MEMBER WALLIS: So you can blow a hole in one side of it or near that side.

MR. THEOFANOUS: No, actually what we have done here to account for that kind of thing here similarly we have proceeded, if you look at the report again, you'll find that the radial, actually symmetric operation basically with the diameter of ten meters to a diameter of only about four meters. So that means we put the explosion close enough to the wall as if it was coming from the edge of the reactor vessel and what you would see again is sort of very conservative but it gives you an idea that what we've done is a conservative picture.

MEMBER WALLIS: But the stuff that is coming out, you said it's in a jet, a high velocity jet.

MR. THEOFANOUS: It's in a jet.

MEMBER WALLIS: So it could go way off to one side and it could actually go very, very close to the pedestal wall, couldn't it, before --

MEMBER SIEBER: No.

MR. THEOFANOUS: No, it couldn't do that. There is no reason to do that because that stuff is heavy and it's not --

MR. THEOFANOUS: But it's driven by its own gravity. It's not at high pressure.

MEMBER WALLIS: So it's not high pressure anymore.

MR. THEOFANOUS: No.

MEMBER WALLIS: That's a low one.

MEMBER DENNING: That's a different scenario.

MR. THEOFANOUS: It's a different scenario now.

(Several speaking at once.)

MEMBER WALLIS: So it's just oozing out

and falling out.

MR. THEOFANOUS: Yes.

MEMBER DENNING: This is low pressure scenario.

MR. THEOFANOUS: It's a different accident.

MEMBER WALLIS: This is low pressure scenario. Okay.

MR. THEOFANOUS: It's a different accident. We started high pressure scenarios for those that we do DCH. Low pressure scenarios the issue is not DCH but these explosives.

MEMBER WALLIS: And there's nothing in between that could be both?

MR. THEOFANOUS: There is nothing in between unfortunately.

MEMBER WALLIS: Okay.

MEMBER SHACK: It's estimated to 90 percent.

MR. WACHOWIAK: This is Rick Wachowiak again. There's not any way really to get water in the lower drywell in the high pressure scenario. So that's the main reason why we don't have to consider the combined effect. There's just no high pressure scenarios we can find where --

MEMBER WALLIS: You can't drain the pool.

MR. THEOFANOUS: What?

MEMBER WALLIS: You can't drain the pool. Is that it?

MR. THEOFANOUS: No. All right. Next.

CHAIRMAN APOSTOLAKIS: Wait, wait. Comrade Theofanous. Is this a good time to take a break?

MR. THEOFANOUS: Excellent time because we are changing subjects.

MEMBER WALLIS: He presents the stats.

CHAIRMAN APOSTOLAKIS: One other question. There's a lot of slides in your handout. Are these part of the severe accident mitigation or do they include the containment systems performance?

MR. WACHOWIAK: They do not.

MEMBER DENNING: They do not.

CHAIRMAN APOSTOLAKIS: Well, there was an hour and a half.

MEMBER DENNING: Are you sure you want to take a break at this time?

MR. THEOFANOUS: Yes. There is enough for two and a half hours according to the agenda.

CHAIRMAN APOSTOLAKIS: You had 12:30 p.m. to 3:00 p.m. Yes, you're right.

MR. THEOFANOUS: That's two and a half hours. Right?

CHAIRMAN APOSTOLAKIS: Two and a half hours. So let's take a break.

MR. THEOFANOUS: We are midway now.

CHAIRMAN APOSTOLAKIS: We'll be back at 2:45 p.m. Off the record.

(Whereupon, the foregoing matter went off the record at 2:33 p.m. and went back on the record at 2:51 p.m.)

CHAIRMAN APOSTOLAKIS: Back on the record.

MR. THEOFANOUS: So we are in to steam explosions. We're now going to look at the BiMAC itself. From a structural point of view, the BiMAC is supported by concrete which itself is similarly top of basemat. The pipes are schedule 80 pipes. That means one centimeter. We would have pretty significant figures basically for structural purposes. They are 10 centimeters in diameter and embedded into this sacrificial layer which is like 27 meters.

Now the question initially is if you have an explosion here what does it take to crash those pipes. Obviously, if we are sitting and those pipes are right below the explosion and there is enough impulse to crash them, then at least in that location you're not going to be able to shoot the water that you need in order to prevent melt completing.

I do want to make a general remark and put this into perspective. We have like 100 square meters floor area. You have an explosion that is sitting someplace with impulses right under it, the localized impulse. So that's going to be like being hit by a truck. Actually, I don't think it's going to mean very much for the whole function of the device, but I still nevertheless would like to know what an explosion will do to those pipes.

Again, analyze them with DYNA3D and see that they support to each other. We found planes of symmetry so that we could analyze this for extreme detail, representing both the pipe, the wall thickness and the concrete above and below it. The results tells us how the quality of the metal yields and whether the concrete cracks. This was for 220 kilo Pascal per second welding and you see a significant crack in the concrete.

I do want to say that this cracking of the material which is especially important for high pressure material itself, I mean the material is important for basically resisting any oblation in the pipes after you pour in the crack a little bit it carries over.

MEMBER WALLIS: So the pipe's intact, but the concrete is cracked. Is that what you're saying?

MR. THEOFANOUS: I didn't say anything yet.

MEMBER WALLIS: Well, I know.

MR. THEOFANOUS: I haven't said anything yet. I'm trying to put into perspective.

MEMBER WALLIS: I'm just trying to interpret your last figure, the last figure you showed us.

MR. THEOFANOUS: Oh, the last figure, that last figure was to show --

MEMBER WALLIS: You said that concrete was cracked. Now what about the pipe? Is the pipe okay?

MR. THEOFANOUS: For this kind of a loading the pipe is some narrow -- oh, I understand your question. I beg your pardon. In some location where the pipe is incorporated with the other pipe, that is in those similar things, they begin to yield. You take that --

MEMBER WALLIS: But it's intact. It's intact.

MR. THEOFANOUS: It's intact, yes. But we take that to be the beginning of failure of the pipes.

Once it starts yielding significantly even in a narrow area, then that's the beginning of the crashing.

So if we put these results in a probability plot again, for 99 percent of the scenarios we have essentially no explosions. So that is covering for most of it. This is for what we call the low level.

For the one to two meter levels, our results show that you can have a hundred. You can have even more, maybe up to about 150 kilo Pascal per second. So that shows schematically here that there is some distribution that we don't know what it is but that is what is shown on the dotted line. And also it's shown here that somewhere around 200 kilo Pascal seconds or maybe about that you begin to get significant yielding of the pipe.

So that's why then the CFP starts rising over here and the whole intent of this is to show that for the scenarios that we played we have integrity. But there is just no comparison, not even anywhere near. The purpose of that is show that even if by chance you had some small depth like one or two meters, you could begin to interfere with the integrity of the pipes.

MEMBER KRESS: What steam exposed to the

model would be used to get this dots?

MR. THEOFANOUS: We used PM alpha which we used before and to me that is the state of the art. The way it works is you get the melt into the water and the PM alpha which is the mixing core.

MEMBER KRESS: Premixing.

MR. THEOFANOUS: The Premixing core, the PM alpha, it basically tell you what are the possible ranges of special space and time distribution so if melt fractions and steam void fraction. Then we take that --

MEMBER KRESS: That takes care of --

MR. THEOFANOUS: Oh, if you like, we have it in the back of the report. We have the whole evaluation basis of those cores.

MEMBER KRESS: Just one question. What sort of triggering do you have there? Does it trigger --

MR. THEOFANOUS: We use significant triggering. Significant triggering means that once you get the premixture we can put a trigger in.

MEMBER KRESS: The trigger time occurs after you get this premixing volume?

MR. THEOFANOUS: Yes. Right. Any time you have premixing. In other words, anytime --

MEMBER KRESS: You can trigger any time.

MR. THEOFANOUS: Right. So the equation you take is -- since you don't know. Triggering is a kind of a spontaneous event that you don't know how to predict it.

MEMBER KRESS: Yeah.

MR. THEOFANOUS: So you are saying that for all the evolutions with the premixture we are looking for cases where and you know how to drive the quality of the premixture from the point of explosivity. So we're finding the worse premixtures. The way you create a trigger is by taking one cell and mixing the fuel that's there with the water very rapidly. That creates a pulse.

MEMBER KRESS: And that expands.

MR. THEOFANOUS: And that expands and then this calculation is done with M which is an explosion point which also we have fully documented and viewed it and all that and I have in an appendix to the Chapter 21 you will find all the verification basis for the PM alpha but because this was done extensively before I didn't want to bore you with that stuff. So I didn't include it here.

MEMBER KRESS: Some of the members have had the privilege of hearing that before.

MR. THEOFANOUS: Yes.

MEMBER KRESS: Another question I have is you're pouring at a certain rate.

MR. THEOFANOUS: High rate, yeah.

MEMBER KRESS: The very high rate. Can you delay your trigger until you get it all in?

MR. THEOFANOUS: Yes, we can, but at that point what happens is --

MEMBER KRESS: You have too much melt for the water.

MR. THEOFANOUS: Yes, exactly. We are getting into the physics now of the explosion. What happens here is if we have too much melt and we don't have enough water then the melt --

MEMBER KRESS: So somewhere in there there's --

MR. THEOFANOUS: That's what I was saying before.

MEMBER KRESS: Okay. Now I understand what you're referring to. Thank you.

MR. THEOFANOUS: All right. So I think now we are switching to the last topic which is the basemat melt penetration and this is to illustrate the scope of the work and what's all the different loading mechanisms that we have and the different criteria that we have to consider and then we have to challenge if it has integrity or no integrity.

What you see here is there is a thermal loading on the jet impingement. All right. So this is we have local peaking right here because of the oblation depth and you'll find an extensive discussion of that in the report. So I'm not going to go through that here. It's just to show you that you just can kind of impact that layer. And that's why we went into a refractory material so that we can be pretty sure that we're going to pack it.

The second item has to do with thermally loading from imagine now we have this -- which is full of melt and it is a natural circulation and now that's going to produce a thermal loading to the bottom and to the sides and now we want to show that this thermal loading would be possible to be accommodated by loading on the other side that so that it will over here. If this is categorized by decay heat flux, this is a local criteria and this job here is done by taking into account any possibility of the local peaking of the heat flux.

MEMBER WALLIS: So are you doing a thermal shock analysis of this stuff?

MR. THEOFANOUS: Thermal shock?

MEMBER WALLIS: Yes, the sudden thermal loading.

MR. THEOFANOUS: It's not the sudden thermal loading. Yes, we can discuss it if you want.

MEMBER WALLIS: The sudden thermal --

MR. THEOFANOUS: But it's not a sudden thermal loading. First of all, even if it was, it would have no impact in this kind of situation. So two answers. Do you want me to elaborate?

MEMBER WALLIS: So you have or have not done a thermal shock analysis.

MR. THEOFANOUS: Huh?

MEMBER WALLIS: I'm just trying to find out if you did a thermal shock analysis.

MR. THEOFANOUS: No, I didn't do a thermal analysis. I think it's irrelevant to this problem of thermal shock analysis. So if you disagree with me, we can discuss it.

The point I'm trying to make is that this evaluation involves local peaking. So it's not sufficient to say I have this on the floor or I have anomalous heat flux. My heat flux is less than this average. That's not good. You have to make sure that watery you always are below. The water is always below the heat flux. So that is a more sticky evaluation because you're looking for all the peaking of the flux and not so conventionally know that there can be all kinds of distributions. So we need to get to those distributions.

The second topic however has to do with the possibility in the pipe of basically depleting of water as it's boiling out. So that's what defines the size of the pipe. That defines in fact this consideration and this consideration you find the size. You can see very easy, in fact, these are very small pipes which in some ways would be desirable from a structure integrity point of view because they are kind of small and have very, very thick walls. Basically it would be indestructible. But if I did that then I would be susceptible to both this and this. So that's why the ball park stands in the middle because we say we want to optimize that because we were doing testing on that for the COL and we want to optimize the test.

But this one here, that has to do with depletion of the water. It doesn't care if the profile is like this or like that. It really cares about the total thermal power it's putting on the pipe. Of course with that sensitivity, it also demonstrates it doesn't go back the shape.

So two things you're looking for there in this. You're looking actually not two, but three things. We're looking for critical heat fluxes down from the horizontal pipe and on the vertical segment No. 1. No. 2 we're looking for the average like a bounding average heat flux I can have again on the horizontal and on the vertical and this is for this problem and then I'm also looking for the local peaking that they have and this is for that. Then in addition, of course we have the explosions which we just talked about. So those are the topics I want to cover now.

Again, the same picture as before, but now a little bit more detail, I think I'm going to give you more detail about how this thing looks. So now if I look at it from the top, this is what I was telling you before. As you take slices this way, this pipe gets shorter and they get longer. Okay? And we have a main distributor here that the distributor is sized and the downcomers are sized. The downcomers are distinct because they are sized in a way that they will provide no significant frictional resistance compared to the frictional resistance of the two-phase flow over here. So there is no starvation of the flow.

MEMBER ARMIJO: I guess I don't understand that drawing. Are they all pipes or is this --

MEMBER SIEBER: Yes.

MEMBER ARMIJO: So there's pipe that --

MEMBER SIEBER: It just goes everywhere.

MR. THEOFANOUS: Yes.

(Several speaking at once.)

MR. THEOFANOUS: Maybe too --

MEMBER ARMIJO: -- How did that work?

MR. THEOFANOUS: And also presenting the sumps which are by the way not always very well protected in the plants, in previous plants. We want to protect the sumps too and the sumps are important to have there for operational purposes. But you don't want to have bypass of the BiMAC by getting the melt from here to here and then going out into -- this would be a tremendous for the point of view into basemat because you lose a lot of the concrete. So in the two near the edge there, we then worked with the people in the design and made them to be hiding the wall as much as possible. Hiding the wall means increase this dimension, decrease this dimension so they can be covered just like the wall of the pedestal by the pipes.

MEMBER WALLIS: Can we go back again? The sequence of events, when do you turn on the water for this and when does the hot melt come out and impinge on this?

MR. THEOFANOUS: Well, we wait until melt comes out.

MEMBER WALLIS: So it's not water when the melt first comes out?

MR. THEOFANOUS: There is no water from when the first melts come out. The moment the first melt comes out the water is initiated.

MEMBER WALLIS: The moment --

MR. THEOFANOUS: We don't want water there. We have these pipes, the downcome is from the GDCS.

MEMBER WALLIS: So the initial thing is just to heat up of the refractory by the melt. Is that what's going on?

MR. THEOFANOUS: Yes. We are making these pipes to be large enough so that when they open they will flood this pretty quickly. So you don't want to really have the water starting earlier than before.

MEMBER SIEBER: A quick question. Maybe you could, if you melted the entire core and some surrounding structures --

MR. THEOFANOUS: Yes.

MEMBER SIEBER: What level of melt would you get in that sump?

MR. THEOFANOUS: The next slide.

MEMBER SIEBER: Well, I'm looking at the slides.

MR. THEOFANOUS: Maybe the next to that.

MEMBER WALLIS: The next after the table.

MR. THEOFANOUS: It would be better to show you in numbers rather than give you --

MEMBER SIEBER: Well --

MR. THEOFANOUS: Just for example either you can wait or you don't hardly wait. So we're going to come to the next one. What is this here is BiMAC as a fraction of melt pool height resulting in average heat flux. That's the question you just asked. Correct?

MEMBER SIEBER: Yes.

MR. THEOFANOUS: Okay. So here now we have a table that says here is the height of the melt and this is in meters 0.2, 0.4, 0.6, 0.8, all in meters. That's the volume now of the melt. We are converting that volume with the typical density of two tons and then you can see therefore that a typical whole pool with floating melt in it would be about 300 tons. So what you see here is that you have such an amount of melt in the BiMAC, it would be somewhere between 0.8 and one meter of height the melt would be in there.

MEMBER SIEBER: And where does that place it on the side wall? Does it get to the side wall or go back to --

MR. THEOFANOUS: That would be all the space that would be inside of that --

MEMBER SIEBER: Up to where the point is?

MEMBER WALLIS: Where is a meter on that map?

MR. THEOFANOUS: All the way, it would be essentially I think up to about here.

MEMBER SIEBER: Okay.

MR. THEOFANOUS: Now an important point to make here is that remember we're in a low pressure scenario. That means the melt that comes out first would be the melt that is molten at the time and suddenly you would not wait until 100 percent of the melt melts before it fails. It will come out some time before. It will be a fraction of this 300 points that it comes out. So that one is going to come out as one lump in a way.

MEMBER SIEBER: Right.

MR. THEOFANOUS: Any material that comes after out is going to be coming out at the rate in which is melting which is going to be dribbling down.

MEMBER SIEBER: Yes, a dribble. But it could start that way too.

MR. THEOFANOUS: It could also.

MEMBER SIEBER: Also you'll lose the control drive of mechanism penetration and you'll dribble out and then all of a sudden the bottom will come out and you'll dump a load and then from then on it's dribbling out.

MR. THEOFANOUS: Exactly. So then as far as heat fluxes the important thing to remember is that not all material comes together as a melt. So that comes out and you have this and you fill up to some time. Now additional material that is dribbling is going to see a water pool, a cold water pool, and it's going to solidify and it's going to solidify there and it's going to make debris then which however is a fraction of this 300 tons which will not participate in the energy balance of the melt that is loading the BiMAC to the bottom because the BiMAC can be loaded downwards only by the melt, not by the debris that is cooled.

MEMBER DENNING: But potentially it may or may not cooled the debris bed.

MR. THEOFANOUS: If it is not cool that's all right. But you know my own -- the significant fraction of it is going to be somewhere and it's going to be coolable because there's no reason for it to remelt because it is all cool from the bottom anyway. So it's not really into a dry quicker but it's a wet quicker if you like.

MEMBER SIEBER: The part that comes out as a lump --

MR. THEOFANOUS: No. We said it can be a pool.

MEMBER SIEBER: A pool. It's going to be still molten while this other stuff is solidified.

MR. THEOFANOUS: That's right.

MEMBER SIEBER: And it's going to be very difficult to remove heat from this molten pool in my view compared to what it would be. The stuff that dribbles and drips down, that's pretty easy.

MR. THEOFANOUS: Well, exactly. That's why you're putting BiMAC there because if it was easy to remove the heat, then we wouldn't need to put the BiMAC.

MEMBER SIEBER: Even with BiMAC --

MR. THEOFANOUS: Well, then you have to

tell me in a minute how you're going to fail the BiMAC. That's where we're going through in the analysis.

MEMBER SIEBER: Right.

MR. THEOFANOUS: You could always legislate of course that it will fail, but I think the idea here is to --

MEMBER WALLIS: After a while what happens this GDCS pool keeps pouring water into this thing?

MR. THEOFANOUS: That's what's going to happen, the emptying is going to stop and then you have natural convection.

MEMBER WALLIS: But then you have no cooling underneath.

MR. THEOFANOUS: No cooling where?

MEMBER WALLIS: No flow in the pipes anymore.

MR. THEOFANOUS: Natural convection because in the pipes --

MEMBER SIEBER: They don't crush the pipes.

MR. THEOFANOUS: -- are in the water pool. So the water would be coming through the pipes.

MEMBER WALLIS: Oh, so it keeps on running itself.

MR. THEOFANOUS: Of course. If it didn't cool down, it wouldn't do any good.

MEMBER WALLIS: Well, I was just wondering about that.

MR. THEOFANOUS: Of course. Okay. So we have then the torus here and then taking the --

MEMBER WALLIS: Doesn't entrain stop when it goes and recycles around? Is it pure water that goes around? Is there junk in the water?

MEMBER SIEBER: There will be sooner or later.

MR. THEOFANOUS: This is natural convection. It's not forced pumping.

MEMBER WALLIS: No.

MR. THEOFANOUS: -- sump there is suction.

MEMBER WALLIS: The water is on the pool sitting onto of the molten core.

MR. THEOFANOUS: Yes.

MEMBER WALLIS: And there's nothing going on that is putting stuff into the water. It always seems to be so placid just sitting there being cooled.

MR. THEOFANOUS: Yeah. Then we have -- these areas --

MEMBER WALLIS: And you call it cert city. A cert city is not very placid, is it?

MR. THEOFANOUS: Who?

MEMBER WALLIS: This Icelandic lava pool that goes into sea. Isn't that cert city? You called one of your --

MR. THEOFANOUS: That's very placid.

MR. WACHOWIAK: That was an experiment.

MR. THEOFANOUS: Let's look at the steam explosion for a while. That is all but placid. So we take the areas and from the material that's there and from the decay power and the decay power can either be tacked to the material at the time we essentially have all the core, but in respect to the total and then it doesn't change anymore. So you see here the decay power increases because the material increases and in here it reached already all the core, all the fuel. So there is no more than whatever decay here is and this decay heat is taking some conservative value appropriate to the timing of these things, typically a few hours and now you have removed about 35 or 36 of the most megawatts. We take that then and we say how was it removed. It was removed downwards, upwards, and sideways.

What are the fluxes for doing that or the other? The fluxes are as you see here for the upward they go 45 to 100 to 205 to 271. So those are the upward fluxes. The downward fluxes 15, 43, 74, 100 and up, about almost 100. Side flux in this case did not even have any side. It was only on the conical part. After that, 300, 320, 350. So those are average fluxes.

Please keep those in mind because now what I want to do is take these other fluxes and then we'll going to apply to them a peaking factor so we can also find what the local fluxes will be. Now we've done this job with the concrete fluid dynamics basically calculating natural convection and this is actually a very accurate simulation. Those are based on what's called Lusardi simulation. That means they account for all the random movements --

MEMBER WALLIS: Excuse me. This is in the core again?

MR. THEOFANOUS: That's the core. That's the melt. The situation is holding and the important things are that in this high value we get tubal mixing in the main part of the pool. We have stable stratification at the very bottom and you have descending cool layers along the walls because the walls are cool. You have the BiMAC there, remember? So this is cool. So it does that.

The important thing to remember is that in all those problems we have a constant temperature bundle condition because all these things are surrounded by crusts because it is cooled here, here and everywhere. So just crusts. So it's an actual thermal bundle condition. That's why they put another calculation. That's what you find. This is the velocity distribution. It's again tubal over here and it is a nice sliding layer over here.

Now to point out since I have the picture up there, when I have the near-edge channels with the vertical pipes over here, I'm going to have, remember those channels are also shorter in the incline and along that way and what this does is it creates a whole layer on the vertical side that floats along and impinges right in that corner where the incline begins. That can locally load and you want to know about that. They can locally load higher heat flux because of that impingement in natural convection. That's all natural convection and then it surrounds it just like that. So that's what it's stating over here. That can be quite significant. It can be three times the other heat flux locally and you get that only near the edge channels. You don't get that in the other channels.

Okay. So here then is kind of a summary

of all the results and basically we're having a number of scenarios which are defined in terms of what you want of the BiMAC, near the edge, near the center, different -- we find a number of things.

MEMBER WALLIS: What's in the --

MR. THEOFANOUS: I'm sorry.

MEMBER WALLIS: The corium contains the control rods and everything like that?

MR. THEOFANOUS: Yes, everything.

MEMBER WALLIS: And it all stays in there. There is none of it which is evaporates or anything like that. It all stays in there?

MR. THEOFANOUS: Only volatile --

MEMBER WALLIS: Homogeneously distributed.

MR. THEOFANOUS: Only volatile fission products will vaporize from this side of the vessel.

MEMBER WALLIS: Right. They are slowly --

MR. THEOFANOUS: So what we find here is that the up to down, what's important, those are the fluxes, up, down and on the sides and of course, there's no vertical for the near-edge samples because you see there is no vertical segment. The core, it's applicable because there's a vertical segment.

Those are average fluxes and then we take here the ratio of q up to q down and you find that in the -- oh, the important thing is ABC and MNO those are 2D simulations. Two D is much cheaper to do because basically you're assuming that there is no movement in the direction normal to the slides that you are calculating. In a way what that does is it restricts the turbulence. It restricts natural convection, it can only rotate this way, but it cannot go over that way and that has a restricting effect on turbulence.

So as a result of that, the q up to q down is about two in a 3D simulation which is one of those cases C and M basically repeating Case C but in 3D and repeating M in 3D, this ratio is more than three, 3.4, 3.5. And in Chapter 21, there is one calculation of each. This is taken from Chapter 21. Since that time, essentially we had nothing else to do. So we had a lot of time to calculate in between. So we've done lots of those 3D calculations since that time which are very laborious and very computer intensive because now you end up with millions of notes especially on fine grid.

MEMBER DENNING: And those are DNS.

MR. THEOFANOUS: Those are DNS, yeah. Large simulations so you solve in all directions. But any way, we confirmed these values of about 3.4, 3.5

and we're going to probably make an addendum for that but we're going to publish these results in the literature. So in that publication, we're going to add these results.

MEMBER DENNING: Going back to the NES.

MR. THEOFANOUS: NES.

MEMBER DENNING: So this is NES.

MR. THEOFANOUS: Yes.

MEMBER WALLIS: Is the Agency going to accept a design which is only verified by CFD?

MR. THEOFANOUS: I think that is for you to decide.

MEMBER WALLIS: Not me. I was just wondering about the Agency.

MR. THEOFANOUS: Well, first we have to explain to them what CFD is to the Agency and then they have to decide if they are going to accept it or not.

That's why I give you a few more results here so you can get a handle on what we mean by CFD. What's possible to do at CFD?

MEMBER WALLIS: So how confident? What's the probability that you're right?

MR. THEOFANOUS: I'm going to explain to you.

MEMBER WALLIS: The CFD. How do you assess that?

MR. THEOFANOUS: I'm going to explain what CFD is.

MEMBER WALLIS: I understand what CFD is.

MR. THEOFANOUS: Let me explain to you what CFD is and then I'll tell you how confident I am.

MEMBER WALLIS: CFD isn't very good for natural convection, is it? The turbulence model. It's just any simulation.

MR. THEOFANOUS: This is --

(Several speaking at once.)

MR. THEOFANOUS: In fact, we are not going in this area. If you want to talk more, we can talk more. You tried to do with a certain model for example. A CFD will total the results. If you do Lusardi simulation, you get wonderful results. Some of that is in the report.

MEMBER WALLIS: Wonderful, full of wonder?

MR. THEOFANOUS: No, full of wonderful results. Now I knew you were going to be a little skeptical about it so I picked that one.

MEMBER WALLIS: Okay.

MR. THEOFANOUS: You might like that. So one question one might ask, exactly, how good CFD is.

So we are for example of course prepared because of our experiment that we did, the appropriate experiment that we did for the industrial retention for Westinghouse, those are half scale experiments, so half scale natural convection experiments.

We have interpreted that with the CFD. We adjusted the parameters. We have interpreted smaller experiments with other people before us, new experiments, but this one is a big experiment and it's part of the typical hydro-dynamics.

Somebody might ask and we did ask ourselves a more fundamental question. How can we actually predict the stability? When you start something going off, you are going to develop a pattern of rolls of fluid that rises and falls and some very interesting things happen there and we happened to observe them quite coincidentally because we had an experiment that we used for this, for this one.

But we have an experiment that we'll call it the "better experiment" in which we were interested all done up and was interested to know what makes burnout in nuclear boil. We can go into that if you'd like but it's essentially one about burnout. It's a previous -- but we'll come to that by the way in a moment because we care about burnout with BiMAC.

So it's interesting to know what makes burnout and people will tell this all is a super idea and there is interference with the water coming down and the steam going up and it's none of that, nothing of the sort actually. It has nothing to do with the burnout. So we had that experiment which we were doing for NASA.

MEMBER WALLIS: It may have been improved by the NRC.

MR. THEOFANOUS: Yes. They're still around. So we have here this better experiment which was developed for NASA and what this is a 100 micron thickness glass which has on the top of it about 100 nanometers of titanium very good deposited. So it's very, very smooth and it is very almost optimistically smooth. But there are thin, but eventually these are thin. It serves as an instantaneous temperature locally over that whole surface if you can observe it with a infrared high speed camera and that's what we have here. So you have 100 nanometer and this is two by four centimeters, 20 by 40 millimeters.

And we can now see fluxes that are three times equal to it in here even with an anoscopically smooth surface. That's another story. But then when you started off and observe you get some interesting patterns forming. Ah, maybe let's see if maybe we can predict those patterns.

So this experiment was underway. We have laying on the top of this nano-film. Then we have here a glass mirror, a gold mirror, which are to see that whole area with a high speed infrared camera which heightens in high speed. So we run into thousands of frames per second and the resolution is really at some microns. So it's really a very accurate measurement and each pixel will tell us the temperature instantaneously there.

So then this is the moon is very beautiful but again, I didn't tell the space to do it again. So it shows you here the experiment, the development of this runny -- this cellular structure, how it's starts. This is tremendable time and this is what the CFD will give us color coded. So to me, that's really remarkable to catch that. With the velocity and the stability and the development of the cellular structure, you can do very well.

Now I'm going into more mundane things then. The central samples were decided from the table that a bounding downward flash on the horizontal is 100 kilowatt per square meter. By the way, I point out that in these slides this is wrong because the computer played a weird game on me when I was pasting it and this line by mistake was pasted up here. So just put an arrow that shows it on the --

So for the central samples we have 100 and we have applying to local peaking which by the way I didn't point out the amounts of local peaking in the previous. Here is the peaking over here. This is the old 1.25 because you apply to the 100 and get the 125. Here is the peaking on the incline and here is the peaking on the vertical. So applying those peaking factors there give us near-edge samples 100 and 300, that's the factor of three, and the radial channels it's is 320, 450 and that's --

MEMBER WALLIS: What's the BTUs per hour per square foot?

MR. THEOFANOUS: What?

MEMBER WALLIS: What is that in BTUs per hour per square foot?

MR. THEOFANOUS: Okay. Let me see. If you could tell me how much is square foot --

MEMBER WALLIS: Is it 300,000 or something like that?

MR. THEOFANOUS: Okay. So if it's 300,000 then this would be one-third of that. So it would

100,000. I'm just rescaling because everybody knows that --

MEMBER WALLIS: And I know it's completely wrong.

MR. THEOFANOUS: All of those could be wrong. It's very convenient because it's thousands. So now we are running into another interesting topic and that is how much thermal loading will those pipes take. At this time I address that question was for universal intention and people were asking me. Some very skeptical people were saying the bottom of that lower head and very, very bottom is so flushed that in theory you should take zero critical heat flux. But of course, you don't because even however so slight the inclination that we have actually creates lenses and those lenses of water they escape and periodically this happens and as the boiling occurs there, you have a micro-layer forming on the surface and as long as the lenses escape and the flattening of the water happens, we think the time interval is that is less than what it takes to dry that micro-layer, you're fine.

And we demonstrated that this is so by experiment which this was later incarnation of that experiment and the very first experiment. Don't have the picture because it's not a nice clear picture. It was a computer data based, but what it is is basically a slight incline just like models the very bottom of a reactor vessel but in a channel geometry. That's where it's actually relevant to the BiMAC and we have pipes and we filled it up to some point and we let it go in natural convection and we heated it from the top and what you find is those lenses form and escape, and then we've got critical heat fluxes in the very, very bottom of the pool of over 300 kilowatts per square meter.

We went to this channel here because for the standard it was interesting to see if we could get more not for the bottom. Nobody cares for the bottom. It's for the sides because for PWRs you get this focusing effect and we put a channel so that natural convection hopefully would create a smooth current and we decreased the critical heat flux here and indeed it increases it. So here we have the channel geometry of whirlpool configuration of four and this was done for Westinghouse.

Here I showed you the real facilities and it's pretty large. So it was full scale flash of the lower head and it goes into a riser and in the back here, there is a downcomer and there is a condensation time. So you get boiling here with the heat boiling from the top. The width by the way of this, the width of this box which creates the heat is 15 centimeters. So the heat is going downwards, boils. The two-phase flow goes to the riser and we see all kinds of interesting instability phenomenon that occurs like geysering and stuff like that's important for other things for boiling water reactors.

And then up here, the steam condenses in the coil and then we have the downcomer. So it goes like that. So in a full, when we say running in full natural simulation mode, we're running it so that the water is enough to create a continuous flow. But we have also been running in a pool of boiling water which the water is so low here that it doesn't close the loop. So that's what it is.

And here we have, this is a 300 power diesel generator with 400 kilowatts power coming in and this is controlling the power surge so that we could have any power surge we want and so all this good stuff. And here, this guy is a big guy. So it gives you the idea of the size of this.

All right. So Configuration 1 was the one that was natural convection. It was only the very bottom part with a very slight inclination that I was describing before. And this is the critical heat flux expressed as a function of the angle is like that. The characteristic dimensions of that channel was very similar to BiMAC with about 14 or 15 centimeters by 10 centimeters, something like that about 10 centimeters.

Then the Configuration 4 also in the pool volume. That means putting the power over the whole thing in Configuration 4. You see 90 degrees you get about a megawatt which magically, Graham, that's your magic number even though it's vertical and then all those points are what we did for Configuration 4. So for us, that will give you an idea.

For the incline part of our BiMAC, we are about here. So we would expect about 400 kilowatts per square meter for the vertical part. For the vertical pipe we would expect about a megawatt as limits. So that is represented over here. Critical heat flux. This is for the incline section. This is for the vertical section. So this plot is made of two parts. One part is the incline and the other part is the vertical and over here is the heat flux and the black is near central channels. So near central channels with high goes to a maximum but a very small maximum and not strong. That was more near the edge of the channels and then it falls off. Then for the near edge channels, the blue, that it goes to that local peaking that I was describing before. That's because of the descending layer.

MEMBER WALLIS: Now heat flux is defined based on the flattened area or the --

MR. THEOFANOUS: Based on the flat area.

MEMBER WALLIS: Or the two -- the flat.

MR. THEOFANOUS: The flat area, yes. An equivalent flat area and then over here, what you see is the thermal loading on the vertical wall.

MEMBER WALLIS: So an equivalent flat area, don't you mean the actual flat area? You don't know --

MR. THEOFANOUS: Well, the calculation, in the calculation you don't make the boundary like that in a calculation of getting from a wall.

MEMBER WALLIS: You use the superficial area.

MR. THEOFANOUS: Yes. And to put that in terms of the margins are defined in this way and we find margins of course but this is a departure from one in this ratio. So you find the minimun and even that is about 60 percent margin and also near the top of that. Actually, when we run these experiments, we find that this for the BiMAC you find out that this flux here near the end of the incline is going to be much higher I believe because also you have natural convection there. Remember this one also based on full boiling and also I think the other part on the vertical side. So that's what that is.

And so at this point, this is the vertical transposition of thermal loading to alpha G. Critical heat flux is alpha G. Thermal loading is what comes out from the peaking of natural convection. Where the trouble is that you have 60 percent margin to failure. This needs to be remembered to put in context and that's really tough of being extremely conservative on the thermal loading and reasonably conservative for the critical heat flux. So in a way, again there's no intersection between load and fragility and we see the failure of this thing is physically unreasonable.

So for someone then again going back to the question that Jack was asking for the survival of that, that's how we decide those things. We find the loading. You find what is day-to-day failure, compare the two and say okay, you'll fail with that. This is pending of course information because I'll be the first one to say that for -- and that is quite different from the CRD question that Graham asked before.

When you actually want to make use of something of that is of an empirical nature which is the critical heat flux is empirical, what you make sure is, let me finish, you want to make sure that your experiment is really representative of the real condition.

MEMBER WALLIS: Now, Theo --

MR. THEOFANOUS: So therefore I would say that BiMAC as far as critical heat flux is concerned needs to be confirmed with real experiments and we can go into that. Yes.

MEMBER WALLIS: This is my stuff. But you have this corium and sitting on this layer which I thought you said was sacrificial.

MR. THEOFANOUS: Yes.

MEMBER WALLIS: When it's gone, don't the pipes seal the corium?

MR. THEOFANOUS: Of course.

MEMBER WALLIS: Corium interacts with steel.

MR. THEOFANOUS: Yes. Before --

MEMBER WALLIS: Does corium eat the pipe?

MR. THEOFANOUS: No.

MEMBER WALLIS: Why not?

MR. THEOFANOUS: For the same reason, it

doesn't hit the pipe --

MEMBER WALLIS: There are all kinds of Utechics and stuff.

MR. THEOFANOUS: The same reason that it doesn't do that for the --

MEMBER WALLIS: So it's cold.

MR. THEOFANOUS: No, for the same reason it doesn't do it for --

MEMBER WALLIS: Does it crust the --

MR. THEOFANOUS: Because it crusted it. Right.

MEMBER WALLIS: Okay.

MR. THEOFANOUS: Because now corium cannot exist at temperatures of --

MEMBER WALLIS: So the crust protects the pipes, although the sacrificial layer is gone.

MR. THEOFANOUS: Yes. Basically what happens is that it's a self-adjusting situation. If the thermal conduction resistance is more than what the thermal loading is, there is going to be a little bit more until now it's just as much as the thermal loading to the cooling. But it will never eat more than that.

I show just for engineering purposes, I emphasize that because in CFD when you know what you're doing, you actually are making predictions based on basic physics and we talked about that. For that one if you check your calculation and make sure that all the physics are presented, then you're fine. You don't need ULPU experimentation. Even then we have a lot of comparisons as I mentioned before, but this one is totally empirically based. I claim that we cannot really predict critical heat flux yet correctly even on a horizontal pool boiling facing upwards. So I certainly don't want to tell that you can predict it facing downwards or inclined.

So that's why I went through very special pains here actually to show you that on the basis of principles this BiMAC is a good concept and that is principal evaluations. It just so turns out that we were lucky in that we had channel data for ULPU that are quite applicable to both dimensions as well as orientation of interest here. So that gave us a very good idea of what we can expect when we do full scale experiments to BiMAC which in fact you can do full scale. We can actually make full scale without any big deal and we plan to do this.

All right. That is all for the critical heat flux. But we're not finished yet because we said we also want to make sure that there is enough water depletion so that near the end of the channels I end up with a 70 percent void fraction and 70 percent void fraction, I don't know where the liquid is. Most likely liquid is on the bottom but not at the top and I want to make sure they have liquid everywhere to keep the wetting the walls because that's underlined, this rewetting of the walls, to actually very interesting because nuclear boiling in fact is a misnomer here and as it is, even in nuclear boiling in misnomer even on the flood plate faces upwards.

The reason it is a misnomer is by the time you go to near critical heat flux levels actually the whole surface is covered by vapor film and all the cooling is happening with the micro-layer that is hidden underneath that film. So the only difference between a plate facing upwards and the plate facing downwards is in the renewal process of that film maybe thinning and thickening again. What you don't want to do is you don't want to have that film go to zero even for a short time because that's going to be burnout, although for vessel retention for vessels as well as for BiMAC when you have significant wall thickness there is enough thermal inertia and the fluxes are low enough so that even if you dried out temporarily you're not going to go to very high temperatures and before the temperatures get to the first point you're going to still be able to rewet and recover the film.

Okay. So that's -- and we're going to go to that and we're perplexed about that because what do you use it for getting the natural convection and incline in the pipe like that. There is no literature for measure. So I remember that many years ago when I was doing the retention and we were doing the ULPU the French decided to sort of a similar experiment, but they wanted to go more fundamental and they did the SULTAN facility more fundament than us.

We tried to mock up the reactor because I believe that the right way of doing critical heat flux at least at this time is by mocking up the real situation. The French thought they could build a straight channel that is facing downwards, so 15 centimeters just like whirlpool, four meters long, facing downwards. They put it on the platform so they could orient it from vertical to near horizontal and they thought they supplied forced flow through that and they figured that -- they measured pressure drop and they measures critical heat flux. So the idea was that take fundamental data presumably which then can be used in some codes whatever to predict critical heat flux and of course this never happened.

So at the end of this experiment as far as contributing to data for the critical heat fluxes, they contributed zero because at the end then they started using my data from whirlpool. However it did contribute us now because I remember that they measured pressure drop and I said now I can see if I can calculate correctly pressure drops on incline channels of the size of kilometers and there is no other data anywhere to find on that, so sort of sitting there getting resolved.

So we have this nice set of data, very appropriate distances like four meters. We were interested in about four meters or five meters. The dimensions there 10 degree inclination was included in the data. The characteristic length was 15 centimeters. They also got 15 centimeters. The channel length four meters. The pressures were all the way from one atmosphere to I think five or ten atmospheres. I forget now. Power levels accounted to kilowatt per square meter. They get detail pressure drop data and again here from the top.

So we took this and we made a boiling model which was basically an equilibrium model in equilibrium boiling using LOCA Martinelli for the pressure drop modified by as far as the void fraction modified by something that is a function of the inclination and this came out from an obscure paper that nobody knows about. It was published in Thermal Engineering or something in Russia back in the `70s or `60s which they actually did exactly that thing. They took LOCA Martinelli and they found how they want to correct LOCA Martinelli for orientations other than horizontal and by using that, we got actually very nice interpretation of the shorter experiments. So by having this kind of basis, I can say that we are calculating correctly pressure drops through the channels under all kinds of fluxes that will fall even well beyond fluxes I'm interested in.

Having said that, now all I need to do simply check and find what is the gravity imbalance I get in those channels match it against my pressure drop and then I get my natural convection. Simple as that. So now having that, I get this. Here is the heat for different heat flux levels. They must formulate natural convection of course increases as you increase the flux, reaches a maximum and the gradually decreases and that's because of two phase friction up here.

So remember the point of interest for us is from here to here, somewhere inside here and the flow in this situation is very stable. The flow is such that it's actually self exhausting because any increase of void fraction the net change in gravity here is more than the change of friction in the range of interest and that is the definition of having a stable flow.

The next question, the more interesting question, is what is the void fraction. As I said, I didn't want to see here at this kind of flux, I didn't want to see 70 percent void fraction there and fortunately I don't. I see, like in the upper limit, I see 40 percent void fracture. So in the most I'm going to be in some kind of a slight -- because I knew anyway which means bubbles are forming, they are going fast and then very high frequencies of wetting and rewetting in the sense of the micro-layer. So that's the story for this.

So BiMAC then, so besides the point I made already which says that the BiMAC needs to be verified by experiments and what I visualize here is full scale experiments. That means the full dimension, full pipe, full length, vertical downcomer with real power, power shape, whatever I want to do that so I can define the local critical heat flux, No. 1. No. 2, also I want to run experiments which are going to be subscale, maybe half scale or quarter scale, in which I have many pipes, many pipes, which are maybe loaded differently. So I want to see the actions between the channels between the pipes and whether that can have any -- I cannot conceive of any detrimental effect of that, but it's good to really have that and it's not a big deal to get that.

So in addition to those conditions, we say that BiMAC needs to be at least RTNSS and that implies a qualification of function in its design state and this is shown now in terms of principle in development. So this is really the experiments we're talking about in the COL and then in addition the identification of continuing ability to function as design throughout the operating life and that means this will require simply testing of this orientation of control which goes back to the probability of actuating this, measuring and actuating.

MEMBER WALLIS: So it just sits there after an accident for the next ten years or something so percolating away?

MR. THEOFANOUS: I'm sorry?

MEMBER WALLIS: After the accident, it just sits there and it percolates away for the next -- forever.

MR. THEOFANOUS: Well, no because you --

MEMBER WALLIS: Until you get a solid lump and it closes up.

MR. THEOFANOUS: Yes, because decay heat slowly goes away. Yes.

MEMBER WALLIS: But there is quite a long time this thing has to sit there and function.

MR. THEOFANOUS: Well, you don't have much choice, do you? You have it inside the vessel, inside the lower head.

MEMBER WALLIS: It has to be somewhere.

MR. THEOFANOUS: Inside the lower head. It's going to be sitting there the same length of time. But it is better to have it sitting somewhere percolating rather than going through the concrete I think.

MEMBER KRESS: And it's eventually solidified in the radiation.

MR. THEOFANOUS: Yes. Sure. Like I say, I expect that in reality there is so much water there I believe that BiMAC actually will not really be needed. But you want to make sure that you say that's a boundary that just cannot be penetrated. That's the intent of the BiMAC. It can be demonstrated to be true.

MEMBER KRESS: When you did your CFD calculations, the heat flux, did you assume a uniform mixture of the core and the metal and --

MR. THEOFANOUS: Yeah.

MEMBER DENNING: Now is that a good assumption? Can there be separation of --

MR. THEOFANOUS: You can get separation, but really not very much at all to anything. If anything, the separation was actually pursued by some people. I believe not rightly so after our work for the Agency standard but for the purpose of finding you get more heat going upwards than downwards. So for upward heat flux we get separation they go more upwards.

MEMBER WALLIS: So you're --

MR. THEOFANOUS: I worry about downwards.

MEMBER WALLIS: So your water after awhile gets saturated with cesium iodide and stuff like that.

MR. THEOFANOUS: There's a lot of water there.

MEMBER WALLIS: Presumably it does.

MR. THEOFANOUS: There's a huge amount of water.

MEMBER DENNING: When you said saturated, did you mean literally saturated?

MEMBER WALLIS: I mean just --

MEMBER DENNING: Or means gets a lot it in.

MEMBER WALLIS: Gets a lot of it in. I don't know what saturated means. Eventually, presumably dissolving fission products get in the water and it keeps go round and round.

MEMBER DENNING: Sure.

MEMBER WALLIS: So then you get chemistry going on and stuff. There's a lot of term analysis to be done of what it is that you have there that's cooling this debris. It's not pure water.

MR. THEOFANOUS: There's a huge amount of water. Huge amount.

MEMBER WALLIS: That's a qualitative statement.

MR. THEOFANOUS: I can tell you exactly how much it is.

MEMBER WALLIS: No, but I know. I'm saying that there has to be some analysis of what's in the water after a period of time.

MR. THEOFANOUS: That would be a good question to ask --

MEMBER WALLIS: Huge or not.

MR. THEOFANOUS: Then we can --

MEMBER WALLIS: The fouling of your tubes, your tubes foul after awhile.

MR. THEOFANOUS: That's an --

MEMBER WALLIS: Foul after awhile.

MEMBER DENNING: Well, is there debris of some sort in character?

MEMBER WALLIS: Through the precipitation or something.

MEMBER DENNING: Precipitating out of boiling boundary.

MEMBER WALLIS: Right.

MR. THEOFANOUS: Actually the fouling improves critical heat flux interesting enough as you know.

(Several speaking at once.)

MR. THEOFANOUS: Right. In fact real cores that's going to be fouled and they might have a higher margin so you can up the power. All right. So pulling it all together now and that leads us to the end, we have three conclusions or three concluding slides. Conclusion 1 is for the low pressure scenarios and here is a containment phenomena event three, a CPET and what is shown is the major decision points one has to make in order to decide at the end this position of those scenarios. So we have here that's okay.

We have low pressure core melt and water level. We ask the first question. What's the water level in the pedestal because that makes an impact on steam explosion potential failure. So we have three levels defined, already explained the rationale for them and it turns out that this is by far the much more likely. This is like one percent of the cases. This is much less than even one percent because that situation simply we have no other one or we have lots of water. What you have in between is not very likely.

Then we follow this branch and already we said that if we take this branch here, the pedestal damage cannot be excluded. And the question then that we next ask is is the pedestal intact? Okay. We say no. Then the next is are we supplying the BiMAC with water? Are the flooding the lower drywell? And of course, in this case, it's already flooded. So it's yes and then debris successfully cooled and again we need to ask that question that related to BiMAC function and as we demonstrated here on the basis of principles, the BiMAC function would be good and it will be coolable but you put a start to indicate that failure or rather the nonfailure BiMAC function needs to be confirmed experimentally.

So here then we have however a containment failure already because we basically destroyed the pedestal. If we are able to destroy the pedestal we destroyed the BiMAC for sure and therefore that means in all those cases you assume containment failure.

MEMBER WALLIS: The pedestal supports something, doesn't it?

MR. THEOFANOUS: Yes, of course, that's why it's called a pedestal.

MEMBER WALLIS: I know. So what happens when it fails?

MR. THEOFANOUS: Well, I don't think very much actually except failing the containment because this thing as you very well find out is to get a failure of the pedestal by steam explosion. If you fail, you fail locally. You will not jeopardize the structural integrity of the pedestal function. However we cannot count on containment at that point. That's why this is known as assumed containment failure. That's one percent of the accidents.

For all the other cases, we have no damage here. Don't even ask the question. No damage and then here yes, again with very high probability based on requirements we have for these two control and actuation systems. And then here again, pending verification, the BiMAC function correct. So we have for here physically unreasonable in all these cases. For those two cases, we're saying that we are transferring to CSETs, containment system event trees, because now even though everything is fine here, we need to know what happens after five days. Is the PCCS pool replaced with water? What does it take to not have containment heat anymore at that point? So all these systems affect in the next presentation. So that's what that means. This takes us to that.

And this one is the high pressure CPET. The first question of course is is the reactor cooling bundle intact and already I showed you that natural convection is very likely for this reactor as with all reactors because with the high pressure vessel convection of the steam. However we didn't want to come to that on that basis. So we used that in what we're calling our jargon. In Rome we call it splinter scenario. That means since you don't, we can't guarantee that that's what is going to happen, we're going to assume that either that or that happens. So that means we take that as if it was to be the case which means it doesn't fail and that's why this is written in the way that's the ES branch.

And then the DCH containment failure no damage we demonstrated. It won't fail. This is physically unreasonable and we demonstrated this branch with the physically unreasonable. Then we have the flooding and the function. So again if it's all yes, yes, yes, it goes to CSET.

So the conclusion three is a summary of containment threats and mitigative mechanisms on the systems, all the systems in place. So here is like a capturing of them together for the three threats that we addressed and this is the failure marker. Already we covered that.

And here is pretty more crisply what is it that we are putting in place to deal with that. So for example for the DCH we have pressure suppression vents. That's the principal mechanism and we have reinforced confidence support. That allows us to use the high fragility and the events allows to have a limit on how much can be pressurized.

Then on the liner thermal failure is the liner anchoring system. On the lower drywell is also the separation by the lips as I mentioned before. On the explosions the pedestal liner failure here again is the dimensions of the wall and the enforcement what holds it together. The BiMAC failure is the pipe the size of the thickness. So it is structurally very robust and backed up by a lot of concrete.

Then on the BMP, BiMAC activation functions essentially actuation is through rotation but it would be specifically designed to very high standards of reliability and the diverse and I would like to see passive valve action so to make sure all those scenarios we can flood the lower drywell.

Local burnout, natural circulation and the inclination of the pipes, that's what it takes. Next the case for BiMAC, water depletion again, that's natural circulation and inclination and low boil fractions and actually lower heat fluxes also. As we have seen in the local melt-through is the refractory. And I think I have a bunch of back-up slides in case you want to ask me more questions about CFD.

CHAIRMAN APOSTOLAKIS: Any questions from the members.

MEMBER SHACK: If you don't credit the BiMAC, is the melt spreading and heat flux you get for this comparable to the ABWR?

MR. THEOFANOUS: Yes. In fact, more.

MEMBER SHACK: More.

MR. THEOFANOUS: And in fact like I said, we could have easily have taken, not easily, but we could have taken the approach to say EPRI criteria and just like ABWR and then just argue that we can take a 72 hours or more to eat through the concrete. That was again sort of the traditional approach, but it's not good. I think maybe we should make sure these reactors are having something that we are sure that this will not penetrate.

MEMBER WALLIS: Well, it's a very impressive story. I'm just wondering what you have to do to convince the very skeptical agency, the very conservative regulatory body, that they can accept this with a lot of confidence.

MR. THEOFANOUS: I think that what we need to do is that we need to for sure make BiMAC experiment which as I said before we can do it full scale. That's why it's convenient.

MEMBER WALLIS: But you're going to simulate that corium heating electrically. We're not going to have real corium --

MR. THEOFANOUS: Of course.

MEMBER WALLIS: So there are always going to be questions about --

MR. THEOFANOUS: I'm sorry. I'm sorry, Graham. A kilowatt is a kilowatt and a meter is a meter. Now if you want to be conservative so you can begin to realize the units of thermal power then I throw my hands up.

MEMBER WALLIS: I'm not saying what I want. I'm just asking questions. That's all.

MR. THEOFANOUS: I wish it was about safety rules in that category.

CHAIRMAN APOSTOLAKIS: Any other questions? Okay. Thank you very much. Let's take a few minutes because we have another hour and a half, guys. Ten minutes. Off the record.

(Whereupon, the foregoing matter went off the record at 4:01 p.m. and went back on the record at 4:15 p.m.)

CHAIRMAN APOSTOLAKIS: On the record. Okay. Next subject is Containment Systems.

MR. WACHOWIAK: Containment systems. So this is the continuation on now from the CPET into the CSET. It think there is quickly two things, at least one thing I want to answer from before. I think the question came up peripherally and I'm not sure it was answered, how did we decide which things went, which sequences went, into the high, medium and low water level categories. Basically, what we did was we looked at the scenarios that got us to core damage. The low pressure scenarios or all the scenarios in fact, but especially the low pressure scenarios that got the core damage.

If it was something that was putting steam into the containment and we were condensing steam on the walls and it was condensate from off the walls just getting down into the lower drywell, then we showed that we're only going to get a few centimeters of water down in the buyback. So we called all of those low. If there was a break in like a drain line or a large break in the reactor called liquid type breaks, if it was a large break down low, not a steam break, but a liquid break, enough liquid from those breaks put a lot of water down in there and it got above that value.

Now we did look at some other things where some of the breaks were kind of in between and it depended on whether or not you had any injection systems working or not like if it was just a break and the water came out, it would be in the medium category. But if a CRD pump was running, it would have moved it up to the high category, so maybe not quite enough to cover the core, but enough to add a little bit of water. And so it was kind of in between and there were some of those things in the medium category.

In the end when we went back and we looked at all the different scenarios that we had to try to see where things fell, like in our Section 7, everything in the top set of cut sets that we described, nothing fell into the medium category. It was either high or low.

In this last round when we did the quantification for the containment system event tree we took another look at that with all the sequences that were above the truncation value and there might be one or two sequences that are at the 10^{-13} level that could fall into there. So what we did was for the purpose of the analysis, we just took some from the low water level and we just put it into the medium level. So the low level came out to be like 0.991 and we made it 0.99 and we put .001 in the medium category just to cover those scenarios that might be just beyond our truncation limit. So that's how we assigned all of those by looking at what specific scenarios got us to the severe accident.

Just to be clear on it, the high pressure sequences, we didn't see anything in the high pressure sequences that would have fallen into a medium or high water level category. Those were all low and in the ATWS sequences once again, those all looked like they were low water level. There were a couple right at the truncation limit that may fall into some of the other categories.

MEMBER DENNING: I think that in some scenarios you carefully limit the amount of water addition to prevent overflow into the cavity. Is that true? Isn't that true?

MR. WACHOWIAK: What we did -- Let me answer it this way. We altered the design so that the design itself will limit the amount of water flow into the cavity. When you get the steam environment in the drywell, the steam as we'll see in a minute there goes into the PCCS, condenses and then goes into the GDCS pool. What we've done is we've designed the GDCS pool so that if it overflows, the overflow water goes into the suppression pool. It doesn't go into the drywell.

Things that condense on the wall though will still run down the wall and go down into the water drywall. We've also added to our emergency procedure guidelines instructions that say don't spray the containment unless you are either absolutely positively sure that you're not going to lose core cooling or you know that the core is on the floor. So those are our emergency procedure guidelines because that would be the other way is operator doing something that would --

Okay. And I can't think of the other question right now that I heard on the periphery that we may not have answered, but we'll see when we get through these.

I'm going to talk now about the containment systems. We looked at for the last couple of hours, we looked at the basemat melt penetration, EVE, DCH and the robust design that we have for those scenarios. What we haven't necessarily looked at here are the containment bypass and containment overpressurization and the systems that are involved in addressing these particular things.

So let's start out with the simple one, the containment bypass. How can you get a containment bypass? You have big penetration that's open to the containment at the time that you have the severe accident. So we went through our list of penetrations that are in the design. They are all listed in the Chapter 6 of the DCD and we did an evaluation. They are all either normally closed during operation, connected to a close system inside the containment, connected to a close system outside the containment or have already been addressed in our break outside the containment evaluation in the Level 1 analysis.

Our conclusion is then that we really don't have a credible bypass scenario here. There are a couple caveats on that. No. 1 is there's a bunch of little penetrations that haven't made it in the detailed design phase that we talked about in the third column here this morning. We don't really know what those would be. We're pretty sure how they would come out, but we just don't know yet.

Then also some of these that are connected to some of these other systems may be periodically operated during the operation of the plant a very small fraction of the time. But there is a chance that they'd be there. So we retained in our containment system event tree structure the possibility of having the containment bypass from one of the penetrations being open. And the way we addressed that was we looked at what is the likelihood that we're going to have a severe accident where the control systems for these isolation valves would not be available and that's how we kind of assigned the value there.

Containment isolation valves tend to be failsafe. They fail closed when they lose power. They go in the right direction that we want them passively. So the control system is really the key factor there.

MEMBER SIEBER: Did you make any assumptions about vents and drains?

MR. WACHOWIAK: Vents and drains are in the detailed design phase that we don't have that information and support.

MEMBER SIEBER: I mean they are usually pretty small. On the other hand, it's an opportunity to have a bypass.

MR. WACHOWIAK: Pretty small. Now we know what we did in the ABWR analysis for the total of containment bypass, but we really needed to know the detailed information on those small penetrations to figure the aggregate of all those. That will be done again just like that in a later phase. But once again, we did retain this here trying to make sure that we capture the phenomena.

Now overpressure protection, our function for overpressure protection is provided by the passive containment cooling system and it can also be provided by the fuel and aux pool cooling system and then finally, if there's a, if we get into a really bad situation now, we could go and do a controlled manual event of the containment through the suppression pool to the elevated release point.

Just like at Level 1 like we talked before, we have a passive function backed up by an active function backed up by a redundant active function. So the robust nature of how we deal with the containment overpressurization. Let's talk about some of the individual pieces of this.

The PCCS operation during a severe accident. In the first 24 hours, there is nothing that has to happen. It's completely passive. As a matter of fact, we have some analysis that shows it's significantly longer than 24 hours. It gets out toward a two-day period, but the design spec now has to be for 24 hours. There's enough water there. So 24 hours in, nothing has to happen.

Steam in the drywells condensed return to the drywell. It's a closed system. Now in the scenarios where we're looking at this in the severe accident scenario, remember from the containment phenomena of entries, we've already passed through the question did the deluge line to the BiMAC work. Did those lines open? So even though the PCCS goes back to the, sorry, the GDCS pools, those lines are open from the GDCS pools to get it back down to the BiMAC again. So it is a closed system here.

There is some residual risk if you will

that has already been addressed in our quantification of looking at the lower branches where the deluge lines have failed. For the CSET, we always have those lines open.

The aerosols that are generated and get up through the water, that's an interesting question about what's ultimately retained in that pool of water there, but what we've seen is that they're carried up with the steam, condense in the PCCS and the aerosols are actually not deposited inside the PCCS heat exchangers themselves. It's carried with the condensate back down into the mixture of water that's back in the containment.

The only real issue that we have here is how much non-condensable gets up into and held up into the PCCS. If we do have non-condensables there, it reduces the effectiveness of the system. There is a vent line that's provided and in a couple minutes here, I'm not sure exactly where the slide is, but we'll explain exactly how that works. It does have this. It requires our vacuum breakers, suppression pool to drywell vacuum breakers, to remain seeded in order to make the thing work.

So the situation here is on the drywell side the steam gets into the heat exchanger. The pool outside boils. The condensate comes down through these lines here and comes back to the GDCS.

MEMBER WALLIS: There must be some kind of way of separating the condensate from the non-condensables which has not been very clear in this picture.

MR. WACHOWIAK: Yes, it's difficult to see in this picture. I agree with you, but these are really a pipe within a pipe kind of arrangement to minimize penetrations. I think that's how it was described to me. The condensate comes from the bottom of these.

MEMBER WALLIS: So the non-condensable line goes up inside the other pipe. There's a different --

MR. WACHOWIAK: And the non-condensable vent line goes up inside so that it's at the top of these end bell tanks so that the condensate -- And because this system condenses faster or at the same rate or faster than it's being supplied, I'm sorry. It condenses at the same rate it is being supplied and the drain goes out faster than it's being supplied. In order for this to work, the drains have to be open just like you're taking a shower. All the water goes down into the drain there. It's coming out of the showerhead and going down in the bottom. A similar sort of thing, it's condensing in here and falling out through the bottom and so this tank here is mostly empty. The top of the tank has non-condensables and steam mixture there.

This is piped directly into the suppression pool and it shows a sparger here, but it could be an open pipe. It really doesn't matter. All that really matters is that the submergence of this pipe is less than the submergence of these events. Then you always have a differential pressure between the drywell or the inside of these valves is the same as the drywell and then the drywell pressure is higher than -- I'm sorry. The differential pressure between the end of this pipe and in here, that column of water, is going to be the difference between --

MEMBER WALLIS: Where is the level in the vent pipe reaching and where is the level in the --

MR. WACHOWIAK: The level is in the vent pipe is always going to be the same as the level --

MEMBER WALLIS: The same as inside.

MR. WACHOWIAK: Yes. A small difference.

MEMBER DENNING: No wait a second.

MEMBER WALLIS: No, it's not.

MEMBER DENNING: No, but when you have pressure in the drywell, then it's going to drive it down to the submergence and that's where you get your head to drive.

MR. WACHOWIAK: Oh, that was your question.

MEMBER DENNING: Yes.

MEMBER WALLIS: Yes. It's down there.

MR. WACHOWIAK: Water in the vent will be, in the vertical vents, will be here.

MEMBER WALLIS: But it will be driven down eventually to the vent, won't they?

MR. WACHOWIAK: No, because the flow tap is through the PCCS into here. So it equalizes out around here.

Now it does fluctuate some going in and out. What the TRACG analysis kind of shows is that this will tend to burp if you will as it builds up some non-condensables. The heat transfer is a little bit less effective. The pressure goes up. It drives the water column down and pushed the non-condensables out and they kind of equalize out there. So this is one of these what again is one of these self-limiting processes such that the only heat that it can remove is how much steam is going into it.

So in the end, we end up with a constant pressure that stays at that constant pressure essentially forever. The only way that the pressure in the containment goes down is due to heat transfer through the side walls and outside that way. But no excess heat is transferred out from the PCCS.

MEMBER WALLIS: Well, conceivably, the pressure could get to be less in the drywell than it is in the wetwell.

MR. WACHOWIAK: If that happens for some reason --

MEMBER WALLIS: Can you open the vent valve?

MR. WACHOWIAK: There's a vacuum breaker here. Now this is from two separate drawings, but it's meant to show that here's the suppression pool here. Air space of the suppression pool, we have this device here that's a vacuum breaker and there is three of them.

MEMBER WALLIS: You send some non-condensables back out again.

MR. WACHOWIAK: You can send some non-condensables back out again and the whole process recycles or it doesn't. It's one of these things that you just can't tell for sure whether they're going to open and reclose or not. The way that this is designed is it's really like a garbage can lid.

MEMBER WALLIS: But it has to close to make the sparger work, doesn't it?

MR. WACHOWIAK: It has to be reclosed to make the sparger work. The way that it's designed though is that there's really no way, it's not like the vacuum breakers on MARK 1 that are kind of like a hanging check valve. It's a positive direct action seating by gravity of this. It's a total vertical and it's arranged such that the failure mode is very unlikely for reseeding that vacuum breaker. However, this seeding surface is instrumented and if for some reason it's detected that it hasn't seeded right, there's a butterfly valve that is inside this thing here that can switch positions and isolate that vacuum breaker so that if it's leaking enough it's isolated on its own. If the containment pressure starts to go up again an indication of something gone wrong possibly with these, we would have procedures that would tell the operators to cycle through and try to close those to see if that's the problem. So we do have a way of isolating the failed backing breaker.

MEMBER SIEBER: You built the prototype to test this, right?

MR. WACHOWIAK: I believe so. We did.

MEMBER SIEBER: I've seen pictures of it.

MEMBER WALLIS: Stay in the suppression pool. Above the suppression pool.

MEMBER ARMIJO: Are there a number of those?

MEMBER DENNING: It actually cools down.

MR. WACHOWIAK: Three vacuum breakers, six PCCS heat exchangers.

MEMBER WALLIS: So all that gas is to go in there.

MR. WACHOWIAK: So that is an integral part of the containment system. We consider these a passive type component. Gravity is holding them in place. It's a positive indication that it's the way that it's supposed to be. I kind of went through this and it can be isolated.

Let's look at the PCCS itself. There's really no way of failing this thing in the first 24 hours. It's open. It provides the heat transfer. The physical arrangement is what makes it work. So outside of the vacuum breakers there's really not much in the first 24 hours that can happen here.

However after 24 hours, somewhere before 72, we need to have more water added in. There is --

MEMBER WALLIS: Now wait a minute. There is no way for it to fail? Presumably there is some debris which can be carried around with the steam and get into this thing and block up the non-condensable lines for instance.

MEMBER SIEBER: Twenty-four hours.

MEMBER WALLIS: Lock up the condensate drain with some debris which flies around and can get up there.

MR. WACHOWIAK: I think debris was addressed in the testing of the PCCS.

MEMBER WALLIS: Only fine debris would probably block up that condensate line, wouldn't it?

MEMBER SIEBER: That line is a pretty big line, right?

MR. WACHOWIAK: Yeah.

CHAIRMAN APOSTOLAKIS: A big pipe.

MEMBER WALLIS: But you said it's unreasonable to consider. Am I doing something unreasonable?

MEMBER SIEBER: Again.

MEMBER WALLIS: Taboo?

MR. WACHOWIAK: I guess maybe I choose my words improperly there. Maybe not unreasonable to consider but --

MEMBER WALLIS: If there were flying debris you could in fact conceivably block something that is essential to the operation of the PCCS.

MEMBER SIEBER: It could.

MR. WACHOWIAK: Like I said, the aerosols were looked at in the test program for the PCCS and that wasn't determined to be a failure.

MEMBER WALLIS: It would have to be particulates of some sort.

MEMBER MAYNARD: I think you created a challenge with that statement there.

MEMBER SIEBER: They were called HU, highly unlikely.

MEMBER DENNING: What about molten --

MEMBER WALLIS: Are they all reasonable?

MEMBER SIEBER: Yes, right.

MEMBER DENNING: What about molten material during the high pressure? No, that's later.

MEMBER WALLIS: Well, it's latent debris. Someone just left something around the containment.

MR. WACHOWIAK: We have looked at debris like that, insulation and things like that, and I believe in the design there is a guard there to keep flying material in the LOCA situation like insulation and other things that would be expected during a blowdown that could affect that. So that's been addressed. It's the particulate fission products that I believe we'll find the answer to that in the test report for the PCCS.

We do have an automatic way considered. It's considered in our analysis. We do have an automatic makeup. The pool reactor for that refueling cavity in the laydown area that's for the steam dryer and separator for refueling purposes, that's all filled with water. Somewhere after 24 hours before 72 hours, those valves will open up pretty much based on level in the PCCS ICS pools providing enough water for 72 hours worth of operation. Beyond that, we still have a connection to the firewater system that could add water there. FAPCS can add water. We could even make a connection to a hose station outside the reactor building and have a fire truck put more water in there.

MEMBER SHACK: So considered in this case means possible.

MR. WACHOWIAK: Its automatic makeup. When I said considered here, I really mean what did we put in the fault trees when we did this analysis. So we put this in. We really didn't put that in.

MEMBER WALLIS: You didn't put what in?

MEMBER DENNING: PCCS.

MR. WACHOWIAK: Spontaneous failure of the PCCS.

CHAIRMAN APOSTOLAKIS: Is there manual action in the venting?

MR. WACHOWIAK: It's in there.

CHAIRMAN APOSTOLAKIS: And you said that it was because -- when you do sensitivity analysis?

MR. WACHOWIAK: In Revision 0 of the PRA we did not do that. In Revision 1 that we're finishing up part of that chapter as we speak now, that's one of the considerations that we're doing in there. We recognized that we missed that in --

CHAIRMAN APOSTOLAKIS: So which one do we have, Rick?

MR. WACHOWIAK: You have Rev 0. We did not give you Rev 1 of Chapter 11.

CHAIRMAN APOSTOLAKIS: Okay.

MEMBER DENNING: How do we test the system and how frequently is it tested and how do you test it to make sure that it would operate, you know, that there isn't something that's happened during normal operation that it's led to corrosion?

MR. WACHOWIAK: During the outages, these are part of the inspection program.

MEMBER DENNING: They are inspected, but there's no testing possible. Is that true? Or how do you -- You can't test them for function.

MR. WACHOWIAK: No. At least not the installed ones.

MEMBER SIEBER: Sort of an inactive passive system.

MEMBER DENNING: This requires heat condensed to make it really work.

MR. WACHOWIAK: That's correct.

MEMBER WALLIS: Well presumably if there's any moisture in the drywell in normal operations and it would very slowly set this thing off.

MR. WACHOWIAK: Well, not really because there's an active drywell cooling system that provides much more steam condensation effect than this would be subject to. So you wouldn't see it there either.

So when we go through the analysis, we find that the PCCS failure including the vacuum breaker portion of that is unlikely in 99 percent of the core damage sequences.

MEMBER WALLIS: What does unlikely mean? Is that 10^{-5} or something?

MR. WACHOWIAK: In 99 percent.

MEMBER WALLIS: The term unlikely doesn't mean anything to me.

CHAIRMAN APOSTOLAKIS: No, in 99 percent it's extremely unlikely.

MR. WACHOWIAK: I've done the reverse on this one. It's not going to fail in 99 percent of the cases.

MEMBER WALLIS: So essentially it's zero. You mean it's essentially zero.

MR. WACHOWIAK: There's a 0.1 failure rate or 99 percent reliability.

CHAIRMAN APOSTOLAKIS: No, no. It's not the same thing. In 99 percent of the sequences it's extremely unlikely. That's what that means.

MEMBER DENNING: That's what that means, but is that what he means?

CHAIRMAN APOSTOLAKIS: Is that what you mean? One percent is not extremely unlikely. That's not -- You cannot mean that.

MR. WACHOWIAK: Let me get to my next slide if it is what I think it is. It's this picture here and I'll explain what I meant by that because the statement was accurate and I think we're all probably saying the same thing. So let's make sure we get to there.   The way we quantified this containment system of entry, remember we're coming in after asking the deluge line and all the rest of those things. For each of the different accident subclasses that we would have that would affect things like vapor suppression function, this includes FAPCS also in case there is an issue there.

Things that would affect these, what the conditional failure probabilities of these headings would be, we made different accident subclasses and we take all the cut sets upon the sequences and add to those different accident subclasses and append these functions and calculate what the subclass specific split fraction would be for each of these functions. So in 99 percent of our core damage sequences, these numbers are like 10^{-6}, 10^{-4}, 10^{-8}.

CHAIRMAN APOSTOLAKIS: That's interesting.

MEMBER WALLIS: That's what you're saying.

MR. WACHOWIAK: Yes, in one percent of the sequences this note here is about 0.7. 0.6, 0.7.

MR. WACHOWIAK: So that's extremely likely then.

MR. WACHOWIAK: And that's why I said in 99 percent of the sequences it's extremely unlikely. In one percent of the sequences, we're probably going to get to a containment event. So what we would say there is that the reliability to overpressure protection is about 99 percent.

CHAIRMAN APOSTOLAKIS: And tomorrow you will talk to us about the seismic effects.

MR. WACHOWIAK: Very briefly, yes.

CHAIRMAN APOSTOLAKIS: But these numbers don't change when you consider earthquake.

MR. WACHOWIAK: What we did for seismic was a seismic margins analysis and we only considered the safety related systems. So what we were attempting to prove with that is that all of our safety related functions would remain operable up to I think it was two times SSE or 2.4 times SSE, something to that. So we really didn't get into what the degraded reliability of these systems would be in a seismic event. So if that was your question, we didn't do that in the analysis. I wasn't really going to talk a lot about seismic. It's fairly -- It's a simple margin.

MEMBER DENNING: In this one percent, what is it that makes them vulnerable? Is there some obvious aspect of that one percent of them that means that you're --

MR. WACHOWIAK: They're in high pressure sequences. The reason you would end up having a high pressure sequence is basically because all of your DC power has failed and amongst other things too, but mainly they all involve no DC power. If you don't have DC power, we're relying on the operator action to provide that extra water to the PCCS. That's why we end up with a very high conditional failure probability there.

MEMBER DENNING: We have 24 hours to do it.

MR. WACHOWIAK: Once again, we tried to do a screening analysis and we're trying not to overly rely on operator actions, but that tends to be what it is and even the operator action that we have, we're not at the point yet in the design that we're sure that you can do that operator action in all cases with no DC power available because you have to get up into -- To locally operate that valve, you have to be somewhere that may not be a very nice place due to radiation to be to manually operate those valves if you're in that kind of a cinder accident. So we really aren't taking much credit for the manual action when you don't have all your DC power systems.

Just to go through it, we solved all these for the different subclasses, some things off on the end, and that's where we come up with our input for the release rates or for the source terms. But in general, jumping ahead of myself here, for the containment failure probability due to overpressurization, it really comes down to that one percent.

Now one of the things that we want to talk about is what happens in the case where you lose the ability for the PCCS to operate. What happens if you lose containment heat removal? Just to get an idea of when the containment is going to be vented or when the containment is going to fail, we hypothetically said let's not have any containment heat removal from time zero. We don't have any scenarios that get us there with any significant probability, but let's just look at what happens if we start there.

We're seeing that it's more than 24 hours before you get to the point where the operators are going to consider that they would need to vent. Now let's move that into our scenario that we had was a one percent that was on the long term failure of the containment heat removal. That failure is not going to create release here and we think it's more like out here. So you still have another 24 hours after that. So we're talking about a 48 hours before you really have to vent and that's time that you have to figure out how to get more water up there and do something else. So it's really a long term scenario in the containment overpressurization. It's not something where we're going to get a failure right away.

Now what we did for calculating source terms, we took a much more conservative approach than that and looked at things earlier. The code for calculating the Level 3 doesn't really deal with those long type of scenarios, so we added some of the hypothetical on that side.

So here are the results we come up with. Bypass we believe is negligible. Overpressurization within 24 hours is negligible. Overpressure later than 24 hours can occur. Some high pressure sequences once again about one percent. There is mitigation there. It would be a filtered release, but as we agreed up front on this project that we're just going to call those releases.

MEMBER DENNING: I'm sorry. Did you say that we're just going to call those releases? You're telling me that you would not take credit for removal of iodine and things like that?

MR. WACHOWIAK: When we used it to calculate the source term for the level three.

MEMBER DENNING: Yes.

MR. WACHOWIAK: We factored in the vent

through the suppression pool. So we took the reduced source term, but what we're saying what's the reliability of the containment. We added that in to the one where it says we're going to have a release. Not a big one, but --

Okay. Any questions on this?

CHAIRMAN APOSTOLAKIS: Thank you.

MR. WACHOWIAK: Next we're going to have Sid Bhatt talk about the offsite consequences.

CHAIRMAN APOSTOLAKIS: You have to do this for design certification?

MR. BHATT: We did because I thought we wanted to get an idea of the thought process all the way and see what happens to the final situation and how to --

CHAIRMAN APOSTOLAKIS: Do they have to submit a Level 3 PRA?

MEMBER DENNING: This isn't the Level 3 PRA. It's a consequence analysis.

CHAIRMAN APOSTOLAKIS: What is Level 3 then?

MEMBER DENNING: Well, site specific and things like that.

CHAIRMAN APOSTOLAKIS: No, but I'm curious. I don't think it's required.

MEMBER WALLIS: Are you going to prevent him from presenting?

MEMBER DENNING: But it looks good.

MS. CUBBAGE: I'd have to get back to you on that.

MEMBER DENNING: But the results are fantastic. That's the point they're going to make. So why not make them?

COMM. MEMBER BRADY: You actually are driven from the goal.

MS. CUBBAGE: Someone had just mentioned that the severe litigation design alternative review, this factors into that.

MR. BHATT: Traditionally, whenever we had once upon a design like ABWR, we used to carry this all the way to the end to see level one, level two and then probably get resuming certain code as you can see and resuming some numbers for the containment phenomenalogy event tree like CPET, what of that, serial accident phenomenon that you want to analyze and then also look into the systems, containment system and suppose they fail, how they all converge and they provide essentially some kind of a key information from the fault tree on the right hand side, some lump end states like bypass, like how to go through those kind of categories.

As you do the fanning process, it's important to kind of figure it out and say where are we are going to go from the offsite consequences for a review for a generic path that we do not have yet a site specific. So this is an attempt. So we created -- I will go through three parts, goals, what kind of process which we have been going through, it's nothing new, what are the results and how does it compare to the goals we tried to look for.

So we created three kind of goals which traditionally we have been using. One is the individual risk and again we are looking near the vicinity of the power plant and we used the reference which is given from the National Safety Council essentially defining some kind of a goal --

MEMBER KRESS: Is it basically the QHOs?

MR. BHATT: Yes. So the second part of this, it is also similar to that.

MEMBER KRESS: Who are you going to go to societal leaks? It doesn't fit my -- of society.

MR. BHATT: Yes. Understood That's the reason why I cannot put it in any other designation. The to-debt context is comparable.

MEMBER KRESS: It's still an individual

risk.

MR. BHATT: And this is an individual risk.

CHAIRMAN APOSTOLAKIS: It's called societal risk.

(Several speaking at once.)

MEMBER KRESS: That's the reason why I quit calling it that.

MEMBER WALLIS: When it comes to something like less than one in a million for the societal risks, less than that, isn't it?

MR. BHATT: Yes.

MEMBER SIEBER: Tom wants it to be --

MEMBER WALLIS: Less than 10^{-6}.

MEMBER SIEBER: - less than 10^{-6}.

(Several speaking at once.)

MR. BHATT: And the third one is to create certain sources as you meet certain failures have occurred that's caused the core melt to come out. Now you do have sufficient productivity (PH) scenarios and then if it's released out from the plant in different situations, one way certain things are still there but under technical specification, it allows you to have some kind of a controlled release.

MEMBER KRESS: Where does that third goal show up in the regulations?

MR. WACHOWIAK: It shows up in the URD.

MEMBER KRESS: Oh, that's a URD provision. We don't have it in the regulations.

CHAIRMAN APOSTOLAKIS: What is it that we don't have now?

MEMBER KRESS: That third goal.

MEMBER SHACK: We just calculated in the Environmental Impact Statement though.

MEMBER SIEBER: Yes.

MR. WACHOWIAK: Rick Wachowiak from GE. I believe the customers use it in their site --

CHAIRMAN APOSTOLAKIS: Yes, but it's not part of the QHO.

MR. BHATT: So the whole process is trying to get an idea about what's the variation risk. When you look into it from the point of view of the boxes are intended to kind of get a focus on what the synthesis is all about to kind of get an assessment and kind of gives you a sanity check. The inaccuracy or accuracy of the probabilistic risk assessment numbers will depend upon the upfront like CDF, CSCD, things like that. So they are filtered in.

Also you would have to look into what kind of fuel was loaded into the core and for example what kind of a cycle you are using. If you expose the fuel for a longer time, you have bigger fission inventory, things like that. So that one is calculated by the core entry point of view for ESPWR but at this point in the presentation, you say they are going to running for a 24 month cycle.

In terms of the upper lefthand part, we already talked to you about the Level 1 PRA. We are calculating CDF, looking into the cut sets and creating bins, defining what is the containment event 3 and the Level 2 type of probabilistic risk number. So all that part provides a certain kind of release frequency for those kind of release categories.

Now if you know the release categories, then you say how are we going to calculate the detail fission product release to create a source term and then synthesize source term and release frequencies and using a computer code which has traditionally been used to calculate the consequences.

MEMBER KRESS: Is that the EPRI version?

MR. BHATT: Yes. So what happens is that curricularly was modified to actually look into the ESPWR essay (PH) features and was benchmarked as the track to have comparisons for the design base accidents so that you can say when the accident starts, at least the initial point also is okay. There is a separate report which we have provided. I think EPRI provided to NRC. Right? And you have that.

So essentially it can also be done by some other code track, mel code, etc. the release fractions. So if you propagate this synthesis process there essentially you do have a source term associated with these different release categories. In this analysis we have 11 of them and for each end state of the CETS for example or the release categories, the radionuclides were lumped into 12 different groups and then we looked into the consequences at the end of the 24 hours and at the end of 72 hours.

MEMBER WALLIS: Well, the worst consequences seem to be when the BiMAC system fails.

MR. BHATT: Yes.

MEMBER WALLIS: And it makes a tremendous difference.

MR. BHATT: Yes. Which one is that?

MEMBER WALLIS: It makes a tremendous difference whether or not the deluge system in the BiMAC works.

MR. BHATT: Which slide are you looking at?

MEMBER WALLIS: I'm just reading from my notes from reading the PRA document. I'm not looking at your slides at all. You're talking about release fractions and I said I noticed when I read the PRA document that they depended very much on whether or not the deluge system in the BiMAC worked or not.

MR. THEOFANOUS: May I say something?

MR. BHATT: Yes, go ahead.

MR. THEOFANOUS: Of course it works.

MEMBER WALLIS: Yes, of course.

MR. THEOFANOUS: That's why you put BiMAC in.

MEMBER WALLIS: I know, but I notice how important it is. It's extraordinarily important.

MR. WACHOWIAK: This is Rick Wachowiak again. Just remember how we did this calculation. We said if the BiMAC fails, then we will have that release. We did not try to say if the BiMAC fails what's the chance that we're going to have core retention on the floor without the BiMAC. That question wasn't asked and it wasn't answered. So you --

MEMBER WALLIS: Bring to the surface.

MR. WACHOWIAK: You can't necessarily infer that if BiMAC fails then the release is much higher.

MEMBER WALLIS: Right. I've just looked at the sequence and it says if BiMAC fails or BiMAC doesn't fail. The difference is so when does it matter to any release.

MEMBER DENNING: Does the BiMAC failure imply from this assumption that you don't get to scrubbing the suppression pool?

MR. WACHOWIAK: I'm not sure how that came out in Revision 0. In Revision 1, it makes it clear which ones with the releases from with the deluge lines are successful so we scrub versus the deluge lines fail. So it's unscrubbed. So there is the distinction that's made. Once again, they are containment failures and the probabilities of those are low enough that they're really not driving this answer. But once again, there is a difference there.

MR. BHATT: So Division 1 has the complete story what we have gone through and also of the Level 2 which we used this for the OP and bypass scenarios. It also has the CPETS and the CSETS synthesis done and it goes through the end states which are considered here. There are 11 categories and I will go over those quickly here too.

But this is a short story. Then we can

come back to the point about the release frequencies. The processes where we again did use for the ALWR URD times. In some cases, we are talking about generic one-part law so we had to use certain databases. So population we used for the Sandia report which was -

MEMBER KRESS: The Sandia side, they looked at a lot of sides. Did you chose one of those or what?

MR. BHATT: One other thing is the population density which was on a more convoluted side. So here we kind of make things compounded from the point of view of what might go bad and things like that. It may not be realistic. We also for example I assumed there was no evacuation which again is pushing the limit. Then we did say that all this release are going to be happening at the ground level, not at the top level. One of the reasons why is because we are near the vicinity of the harbor. Now in case of a plume was released also as if it had no heat content. This is kind of my field.

MEMBER WALLIS: You believe there is caloric theory.

MR. BHATT: No, this was --

MEMBER DENNING: Based on what your concern was.

MR. BHATT: What it says is that, yes, we could push out a number. So basically when a generic calculation like that, we did zero, zero, a million, things like that, just to kind of get an idea. Essentially what it does is that the plume is released at the higher level and with the higher heat content it can propogate further and then you are trying to analyze some goals which are near the vicinity of the font then in that situation so this again is pushing the limit.

Then essentially the whole dose at a half of mile is a probably direct sentence (PH). The top line one 10^{-6} is a kind of a goal.

MEMBER KRESS: That's for the atmosphere.

MR. BHATT: That is a goal which we have and the plots, there are two plots on this one, the 72 hours and 24 hours. Essentially they are theoretical scale. The calculation numbers kind of has significant margin.

MEMBER KRESS: Before you leave, the .25 sieverts, is that the 50 percent lethal dose?

MR. BHATT: No.

MEMBER DENNING: Oh, no. That's 25 rem and this gets barely up to the point of health effects.

MEMBER SIEBER: It's the first level of detectability. So back on cell change.

MEMBER DENNING: Nobody's going to --

(Several speaking at once.)

MR. BHATT: This again are the requirements I am saying there.

MEMBER DENNING: Before you get off of that, I think the place that goes into the coordinate there, that's the core damage frequency of the component. Recognize that because what we're basically looking at are things that are down to 1/30th of the core damage frequency. That's kind of where we're going here.

MR. BHATT: Yes.

(Several speaking at once.)

MEMBER KRESS: This is the SC curves that we're talking about.

MEMBER WALLIS: This is cumulative probability consequence.

MEMBER KRESS: Yes.

MR. BHATT: In terms of how, if you look at the bottom list, probably to what decimal numbers, but you throw out a basis and say this is what it is and then you try to compare them. Then the comparison says that this is the goal which we set for the example for the variation dose which is 10^{-6} and the 24 hour period case, the 72 hour case. We do meet the goal but politically we say you can say yes. In terms of decimal number, I think it's kind of not that significant because we really do not know with that decimal number.

MEMBER SIEBER: Does that include iodine?

MR. BHATT: Yes. The 12 groups.

MEMBER SIEBER: Right.

MEMBER WALLIS: These are individuals risks. So even if there are a million people affected you would still in some cases --

MR. BHATT: So for the site specific --

MEMBER WALLIS: It's a cycle. You have a million people. Multiplied by a million, you still need more. So it's pretty close to a million people.

MEMBER SIEBER: It's an accumulated dose as opposed to a health impact.

CHAIRMAN APOSTOLAKIS: The number of people is a pattern because it's expressed in terms of the individual.

MEMBER WALLIS: Yes, that is individual.

(Several speaking at once.)

MEMBER WALLIS: Even if it is that you modify by a hundred thousand, you would still be within the goal.

MEMBER DENNING: The nice thing is you don't kill anybody.

MEMBER SIEBER: You never get the levels at that distance that are sufficient to cause cellular change. Now it's below the so-called emergency dose that radiation workers are allowed to get.

MEMBER WALLIS: So you can put this in the middle of a city?

MEMBER SIEBER: Not my city.

MR. BHATT: It's not impossible.

(Several speaking at once.)

MR. BHATT: Now when you see the site specific application in the PRA where you would see a certain case like there could be in Washington, D.C. or New York City and there is a plant and what kind of the detail whatever, at that time probably this thing should be revisited. For example, one of our customers is already doing that. In those situations, we would probably get the more realistic.

CHAIRMAN APOSTOLAKIS: So how is it? Did you do any uncertainty analysis here? What are we talking about?

MR. BHATT: Uncertainty analysis --

CHAIRMAN APOSTOLAKIS: You did it for the core damage.

MEMBER SIEBER: It's just a number.

MR. BHATT: This is just a number. For the core damage frequency, the numbers would be from one PRA and --

MEMBER WALLIS: So what's the number --

CHAIRMAN APOSTOLAKIS: There are no uncertainties after that.

MEMBER DENNING: Max.

MR. BHATT: We have propagated the uncertainty. You are right. We have --

CHAIRMAN APOSTOLAKIS: So this 3.7 10^{-11}, how high could it be?

MR. WACHOWIAK: This is Rick Wachowiak with GE. Let me try to answer that in the best way we can because No. 1 we did not try to propagate any uncertainty. So the Level 1 input is point estimate. But if you remember how we did the Level 2, we looked at bounding parameters to get us to the different release bins. We think we're on the upper edge for calculating the frequency, translating the Level 1 frequency into the release bin frequencies.

Then when we took the representative source term, we really looked at what would be the upper limit source. I don't want to say bounding because if we have two cases, one was 10^{-10} and one was 10^{-13}, we tended to look at the 10^{-13} case. But we intended to use more bounding values to get the actual source terms. We put them in here and then max'ed those as Monte Carlo stuff for all the rest of the things.

So did we specifically do an uncertainty analysis? The answer is no. What uncertainty analysis would be applicable to this? It tends to be more on the Level 1 feeding into the Level 2 that would get us there and then we'll use bounding beyond that. So it's an interesting question. I'm not sure that if we think about the Level 1 uncertainty of knowing one order of magnitude at higher infrequencies and propagating that to here that it would really change much of the answer.

MEMBER MAYNARD: Well, you probably had most of the uncertainties there covered by the conservatism that you get built into the parameter analysis like the assumption that you allow your container to contain things that you don't have.

MR. WACHOWIAK: That would be -- in fact, you could probably make --

MEMBER MAYNARD: Or significantly delayed.

MR. WACHOWIAK: So it's a mixture.

MR. BHATT: So essentially this whole story with tremendously surprising results bartered across the -- missed frequencies where coming low and then as you add this to reach down the slow sterns helps. But that's partly the purpose of setting some goals for the Level 1 PRA and Level 2 PRA and trying to come out. So essentially this shows tha PRA tests help.

(Several speaking at once.)

CHAIRMAN APOSTOLAKIS: Is this it?

MR. BHATT: I think so.

CHAIRMAN APOSTOLAKIS: Any other questions? Okay. This concludes the day's presentations. I would like to thank the speakers. It was very informative. So we'll see some of you tomorrow morning. Thank you. Off the record.

(Whereupon, at 5:10 p.m., the above-entitled matter was concluded.)