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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARD

(ACRS)

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U.S. EPR SUBCOMMITTEE

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WEDNESDAY

APRIL 21, 2010

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ROCKVILLE, MARYLAND

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The Subcommittee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B1, 11545 Rockville Pike, at 12:30 p.m., Dr. Dana Powers, Chairman, presiding.

SUBCOMMITTEE MEMBERS PRESENT:

DANA A. POWERS, Chair

HAROLD B. RAY

MICHAEL T. RYAN

WILLIAM J. SHACK

JOHN D. SIEBER

J. SAM ARMIJO

NRC STAFF PRESENT:

DEREK WIDMAYER, Designated Federal Official

GETACHEW TESFAYE

EDWARD FULLER

JIM XU

LYNN MROWCA

ALSO PRESENT:

SANDRA SLOAN

ROBERT MARTIN

MICHAEL BINGHAM

MOHSEN KHATIB-RAHBAR

NISSIA SABRI-GAULTIER

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

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

12:26 p.m.

CHAIR POWERS: Let's get into session. This is a continuation of a meeting this week of our Subcommittee on the U.S. EPR. Today we're looking at the certification aspect. And we're going to discuss Chapter 19.

All the rules and processes for the meeting are about the same, including the fact that we have a bridge line and that everyone that will speak will identify themselves, speak clearly and with sufficient volume to be readily heard, et cetera, et cetera.

And are you going to introduce this session?

MR. TESFAYE: Sure. Thank you.

Again, my name is Getachew Tesfaye. I'm the Project Manager for EPR design certification.

Today, we're trying to complete Phase 3 Safety Evaluation Report with Open Items, presentation of Chapter 19, which is probabilistic risk assessment and severe accident evaluation.

Today's presentation specifically addresses severe accident portion of it that was not completed back on February 18 and 19 of this year.

As I do every time I come here, for the record I will briefly summarize our Phase 3 activities that have taken place to date.

We have completed Phase 3 presentation of nine chapters. We presented Chapter 8 Electric Power, Chapter 2 Side Characteristics on November 3rd and Chapter 10 Steam-Power Conversion System, and Chapter 12 Radiation Protection on November 19, 2009.

On February 18 and 19 of this year we presented Chapter 17, Quality Assurance and portions of Chapter 19 Probabilistic Risk Assessment in Severe Accident Evaluation.

On March 3rd of this year we presented Chapter 4 Reactor and Chapter 5 Reactor Coolant System and Connected Systems.

On April 6, 2010 we presented Chapter 11 Radioactive Waste Management and Chapter 16 Technical Specifications.

In addition, on April 8, 2010 we briefed the ACRS full Committee on the seven chapters that were completed through March 2010.

Although we don't have a firm schedule for completion of the remaining nine chapters, our plan calls for the completion of all Phase 3 activities by early 2011.

Mr. Chairman, that completes my introductory remark, unless there is any question.

CHAIR POWERS: Yes, I suspect we cannot complete Chapter 19 today until we get a report back from our PRA specialist.

MR. TESFAYE: That's true. But I'm talking about the formal presentation.

CHAIR POWERS: Oh, formal presentations will probably get a good start on them today.

Are there any other opening comments that members would care to make about this?

We do have Mr. Stetkar studiously plowing through the details of PRA, and he will report back to us in depth, in detail that anyone could possibly want.

Sandra, I guess your team is up.

MS. SLOAN: Okay.

CHAIR POWERS: Let's see, I am reminded that you're not making your presentation today on mapping all the requirements against Appendix B?

MS. SLOAN: I hope not. Mapping all the requirements? I'm not sure what you're referring to.

CHAIR POWERS: Well, I'm referring to the job that Brian suggest we assign you because you did not attend --

MS. SLOAN: Oh, that job. That job.

CHAIR POWERS: -- our last meeting.

MS. SLOAN: I'll work on the homework assignment.

MS. SLOAN: All right. So I would say this is the unfinished business from the previous Chapter 19 discussion today. The topic will be from Tier 2, Chapter 19.2 on severe accident evaluations. And consistent with the other presentations of the various chapters, our objective is to give you a summary level presentation of how this material is organized in the FSAR for design certification. Our focus, as usual, is on design features, analytical procedures, operational aspects that are unique for the U.S. EPR.

And our presenter today is Dr. Robert Martin. And what I would ask since we have Dr. Martin here, I'd ask him to give his background and credentials and then maybe pause before you start and like Michael Bingham give a little introduction of himself. Mike is here in a supporting role to help answer questions. So maybe the most efficient thing is Mike gives his introduction, which will save us that trouble when we get to the Q&A where he might need to pitch in.

So, I'll turn it over --

CHAIR POWERS: And what do you dislike Mike for? You said it's trouble for him to introduce himself? She must have it in for you or something. Is it a particularly long introduction?

MS. SLOAN: So why don't you give your introduction?

DR. MARTIN: Okay. My name Robert Martin. I'm a nuclear engineer with graduate degrees from Texas A&M and Penn State.

Been with AREVA for 13 years. I've been primarily involved with methodology development, code development with SRAP5 code, methodology development with the realistic large-break LOCA.

I've had a small role with the containment analysis methodology development.

And, of course, my primary task for the last five years is regarding severe accident evaluations.

And, Mike?

MR. BINGHAM: My name is Michael Bingham. I'm a graduate of BYU, Brigham Young University.

And I spent four years working with the Navy doing some analysis, most of the time with Knolls Atomic Power Laboratory and doing some core thermal hydraulic there. So I spent four years there.

And then the last four years I've been here with AREVA doing work with the severe accident group.

MS. SLOAN: And before we start, I just wanted to remind everybody there are no fewer than five pages of acronyms at the end of the presentation. So if you hear something, we tend to speak a lot in acronyms and abbreviations because --

CHAIR POWERS: I know, you're very unusual in that respect. Nobody does that.

MS. SLOAN: But there's a five page decoder ring at the end if you need help on that.

CHAIR POWERS: Okay. What does the acronym AREVA stand for?

MS. SLOAN: It has a history if you want to talk about the name.

DR. MARTIN: Okay. I will I have scripted a little bit here to keep me on track, more than anything to keep me on time.

CHAIR POWERS: You have no control over that.

DR. MARTIN: With regard to my boss here.

Today I'm providing an overview of the content appearing in the U.S. EPR FSAR, Chapter 19, Section 2 on severe accident evaluations.

This presentation emphasizes two keystones, the first being a description of the severe accident prevention and mitigation features. And then the second being AREVA's approach to the safety issue resolution regarding the former. You can see in my bullets here. I'm going to try to quickly get through -- quickly is not going to happen.

But design features, we'll discuss that. And event progression which I think probably is really the more valuable element since this is probably the first you've heard about this U.S. EPR severe accident design features and event progression, at least in the formal capacity. And then, of course, the long term stabilization strategy.

And then the other detail goes into how we used analytical methods to address the safety issues and how we supported that with technical basis derived from experimental programs.

CHAIR POWERS: Well let me with a bit of a philosophical question. Why do we do these analyses?

DR. MARTIN: Well, a lot because it's expected of us.

It focuses us initially, and I'm basically going to get into that basis right here. It's, of course, the regulatory expectation. The regulatory expectation begins with the SECY-90-016, the SECY-93-087 where, as you probably know, there's laid out the expectation for safety issue resolution incorporating analytical means as well as any empirical support that we deem necessary, "we" being the collective we as an industry.

In the SECY-93-087 there are safety goals, as I've listed here, that have identified beginning with hydrogen mitigation and combustible gas control, core debris coolability, containment over pressurization, high-pressure melt ejection and equipment survivability.

This graphic was prepared in our pre-application topical submittal. Of course, by using the word "pre-application," this actually showed up to the desk of Ed Fuller and his team like in October 2006 and he had about a year there to review that examining the 500 pages of content on experimental approach on our approach to analytical methods, how we recognized the particular regulatory precedents, the precedents established by our competitors, et cetera, et cetera. And then we incorporated some sample problems to kind of complete that package.

From that point on we have been implementing that methodology. Again, we started with the empirical basis, test programs. Again, you could took a look at that pre-application submittal to see and there's probably a couple of hundred pages of just the experimental story supporting the U.S. EPR strategy for its ex-vessel mitigation approach to a severe accident.

And then since that time, as I've said, we've focused on the safety issue resolution through analytical means.

CHAIR POWERS: Well, it appears that the entire focus of this, everything you've defined up there as safety goals and related issues, have to do with preservation of the integrity of the containment.

DR. MARTIN: And I would say with severe accident evaluation the emphasis is on that particular fission-product barrier. Now we in devising our analytical methods we are, as I will describe later, certainly incorporating inputs that are, say, Level 1 core damage frequency-informed to, say, define what is termed more likely scenarios. Again, this is information that I have incorporated into this presentation.

CHAIR POWERS: And so that means that you are pretty well discounting any bypass accidents here?

DR. MARTIN: No, no. I mean, bypass of

course, we are expected again through the regulatory verbiage in the SECY-93-087 to address bypass. Now bypass typically safety-grade isolation systems and those are discussed in more detail in other sections. And I do think I get to that, at least touch on it briefly, a little bit later. But this section, 19.2, while there's a large body of information addressing analytical support in protecting the containment, the other relative areas of addressing similar accident issues including the bypass issue is incorporated by cross reference to other sections in the FSAR.

CHAIR POWERS: Well, a casual thumb through your presentation sees that you do not deal very extensively with issue of radionuclide behavior on this entire presentation?

DR. MARTIN: Right.

CHAIR POWERS: And I'm curious as why. Because without the radionuclides, I really wouldn't care. If you wanted to destroy your reactor, I'm perfectly willing to let you do it.

DR. MARTIN: Of course. The issue of radionuclides, at least with us following the Standard Review Plan and the Reg Guide 1.206, the biggest role for analysis regarding, say, radiological transport, source term evaluations really feeds into inputs for

Level 3 PRA in evaluating latent fatalities, early and latent fatalities. And the expectation that I was interpreting from the primarily SECY-93-087 really limited me to the content that I have prepared in this section I can point to, and then the interface primarily with regard to what you've asked, radiological transport, followed on with I believe it'll be sections of 19.1 that touch on Level 3 to some extent. And the staff did identify particular issues with radiological transport that have been addressed through the RAI process as well.

The way we divvy up our work, the responsibilities of myself and my team focused on performing the calculations and the PRA team takes those results and incorporates them into the PRA related analysis supporting those kind of questions.

CHAIR POWERS: Well, the question I'll have for you, you don't have to answer it right now but sometime before the end of the day, is where do I go to look to see how you handled things like aerosol physics, iodine chemistry and the aqueous pool, chlorine reactions with metal surfaces; things like.

DR. MARTIN: Yes. And for our purposes we have, of course the MAAP code performing accident evaluations. Primarily the models do exist for fission-product transport, they exist for settling of fission-products. As you probably know with the MAAP code it is a lump-parameter code, but the models are pretty sophisticated even for a rather, say, less mechanistic type tool. Less maybe relative to say what you're more familiar with MELCOR, something like that. Models do exist.

We have had questions along that line. I know we have an open question, I believe it's 19.3.35 with regard to some discrepancies between the MAAP and MELCOR with a particular steam generator tube rupture-type situation. And so we have been sensitive or sensitized to that type of concern and in discussion with the staff.

CHAIR POWERS: Well, you understand my dilemma here. The only reason I care about this stuff at all is because if you don't preserve containment integrity, or even if you do, you get a certain amount of leakage of radionuclides out and in these severe accidents putting out a lot of radionuclides, I presume.

DR. MARTIN: Of course.

CHAIR POWERS: And I'm struggling to know exactly what you did.

Now, a certain amount of experience, a

very limited amount of exposure to the MAAP code suggests an awful lot of versions of MAAP. And I'm not exactly what version you use. And I know that there are lots and lots of things that get done to it.

DR. MARTIN: Certainly. I'll touch on all these subjects related to how we go about performing our analytical studies. I'll try to be sensitive as I go through to radiological transport.

CHAIR POWERS: Good.

DR. MARTIN: All right. Trying to close out this slide, I guess my final point I wanted to make is that the topical report that was prepared has been incorporated extensively by reference. It provides detail, again, on the test program, analytical methods credited for demonstrating the fidelity and robustness of our design to severe accidents within the contents defined by the applicable regulation.

Okay. As I've already stated, our key guiding document for addressing evaluation of severe accident phenomena is the SECY-93-087 with five primary areas that are identified here. These are emphasized in the Standard Review Plan in Reg Guide 1.206 as requiring a broad level of detail relating to the role of design to prevent and mitigate adverse conditions.

I could go into detail on these, but I would think I could probably touch on these as I go. Later I have some analyses, a limited amount of analyses and I'll probably make a reference to maybe some of the criteria I was shooting for or what I was looking at the time. So I don't think I need to read this slide.

CHAIR POWERS: Well, let's talk little bit about hydrogen control.

DR. MARTIN: Okay.

CHAIR POWERS: In this analysis are you relying on passive catalytic hydrogen recombiners?

DR. MARTIN: That's correct.

CHAIR POWERS: Well, what do you do about poisoning?

DR. MARTIN: Well, that has been a topic that we've been sensitized by the staff. We've had a RAI. I believe maybe Annmarie you offered that RAI.

We have addressed that RAI probably a few months ago with regard to just that line of questioning, aerosol poisoning, fires, carbon contamination. And it was several other things.

I wasn't the key author of that RAI, although I did have a role in reviewing it.

We, I believe, made reference to a considerable number of tests that AREVA has been involved in directly, that AREVA has been involved with at least through its relationship with EDF.

I believe there might have been some other, maybe, OECD tests, there's a PHEBUS test that I think we mentioned several times in that response.

So I would say the answer to that is we had considerable amount of empirical type results to discuss this, as well as some theoretical performance information that would compliment that. But probably focus more on experimental empirical type data in that realm.

MS. SLOAN: And we can make sure we identify that RAI response and make sure you get the text of that.

DR. MARTIN: In fact, it was several RAIs.

MS. SLOAN: Yes. We can take the action to get the particular RAI numbers and ADAMS accession numbers so you can take a look at those.

DR. MARTIN: Although that was Chapter 6, I believe.

MS. SLOAN: Well, we'll look it up.

DR. MARTIN: But I didn't want you to go off in Chapter 19 and look because I believe it was --

CHAIR POWERS: Well the difficulty I have, of course, is that in one of the tests you made oblique reference to involves an environment that is different than the environment that you're going to have when you have corium debris penetrating your vessel and coming down into your core spreading device. And yet it's in that stage where you have the potential of getting abundant hydrogen production. And we know that these PAR devices, at least the ones that I am familiar with, have platinum or palladium which is very reactive toward metals or sulfides. And certainly in ex-vessel stages of accidents we get a lot of sulfides in the atmosphere. And I don't see those in the tests that I know of that you're referred to as qualifying your PARs.

And we go back into the literature of PARS, we find particularly where they have been used for diesel fuels, that's one of their primary concerns, the metals and sulfides and things like that that we get in abundance during these later stages of reactor accident.

MS. SLOAN: I think Dr. Power, I've captured the question that I'm hearing is it will be addressed in Chapter 6. We'll follow-up and make sure that you get the RAI responses and we'll take it and make sure that when we come back for Chapter 6 we address this is that presentation.

MR. FULLER: This is Ed Fuller.

We'll also looking at this a little further for the Chapter 19 review subsequent to your comments at the last meeting, Dana. And we're working in conjunction with Annmarie right now to make sure that we do some confirmatory work as well as formulate possible additional questions.

CHAIR POWERS: Thank you. To we have a TBD down there. And he jumps off this slide quickly. I just started on --

DR. MARTIN: The main thing my wife worries about me going off on tangent and talking too much, but I don't mind talking too much.

Unless there's anything else, I'll move on to the next slide.

Now it sounds like you've done a little bit of homework here and you're cognizant of kind of the main features. Because I have not said the word passive autocatalytic recombiners, but I was going to get to it in this slide.

Here, I'll just try to gloss over real quick and give everyone, just reset their bearings on what we have in this plant with regard to severe accident design features. And as you see, I've in this illustration pointed out the key ones here. And I guess I'd rather go in order of, maybe, event progression.

Assuming a severe accident the first stage of moving into what we'll call the severe accident is when the core exist thermocouples read about 1200 Fahrenheit. Upon receiving that signal, and you know that's still a parameter that we will refine, say, during a detailed design. So it's not the only thing we'll be looking at.

But nonetheless, on declaration of severe accident operators are to be instructed to open primary depressurization valves which reside above the pressurizer. Of course that provides the opportunity to blow down the system with the goal, of course, to prevent a high pressure melt ejection. In doing so, and if you're in a severe accident, you expect in-vessel hydrogen production and hydrogen again escaping into the containment.

The primary mitigation of that hydrogen, as we've just discussed, are with passive autocatalytic recombiners. The performance of the CGCS, the combustible gas control system is enhanced by the design of the containment itself. The term now is the CONVECT system, which comes up with the containment analysis.

Early on we called it a hydrogen mixing system, but the system with dampers and rupture foils, rupture foils appearing above the equipment rooms, above the steam generators and then dampers that reside in the wall adjacent to the IRWST in an outer containment region. In an event in which the inner containment region pressurizes the rupture foils, and there's also these convection foils, which open on temperature --

CHAIR POWERS: One of the things that you have in this containment is a fair amount of compartmentalization and you're providing these relief paths so that you get mixing. What happens if the relief path doesn't open?

DR. MARTIN: Excuse?

CHAIR POWERS: Suppose your relief path doesn't open and I'm blowing this mixture of hydrogen and steam down there. And the steam condenses in the cold structures and I'm left with individual compartments that have hydrogen, presumably, that could be up way into detonable regimes.

DR. MARTIN: Well, we have spent a lot of effort to make that hypothetical situation highly unlikely.

The rupture foils themselves are designed to rupture on a relatively small differential pressures. These are passive systems. I believe the number if 50 millibar, or is it 35 millibar? Thirty-five. Nonetheless, those are passive.

The convective foils, these also can open on a pressure differential but to avoid this situation as you have described, the convection foils by virtue of naming these convection foils, are allowed to open on an elevated temperature. And do you know what that temperature is.

MR. BINGHAM: I don't recall what it is on that.

DR. MARTIN: Okay. Nonetheless, in our evaluation we, of course, tested these things, these components, the rupture foils, the convection foils at facilities in Germany.

The other side of the coin are the mixing dampers. Now the mixing dampers are fail-open on loss of power. They are attached to an I&C system such that a pressure reading, a delta pressure across the dampers of, I believe, it's either 50 or 35 millibar will open so dampers.

So to answer your question our response is that we've incorporated into our design mechanisms to prevent that kind of problem. We do have, of course, passive autocatalytic recombiners in the inner regions of the containment to mitigate high levels of hydrogen there as well as the PARs are outside of that region as well.

CHAIR POWERS: The question I come up with is you had these devices that fail on differential pressures. And you test them, and they sort of do. They're rupture foils, kind of classic design and things like that. And they do it on the design, pretty close to the design kinds of delta Ps. And then you have to show that in fact you get those delta Ps at the time you want them.

And so I guess I'm asking is how do we know that we get those kinds of delta Ps because my experience is with relatively but compartmentalized facilities when I blow hydrogen steam mixtures down, I get surprisingly low delta Ps in mine. My rupture foils never work.

I don't have your design, but mine are pretty much a failure. You do not want a higher major design in your rupture foils, whatever it is. Mine don't work.

DR. MARTIN: Like I say, we extensively

have studied the rupture foils. And I will say that the first time we tried it, it probably wasn't optimal. You learn by that experience. WE probably have a little bit more money to iron our any design efficiencies. And I think we're rather confident in the design today. But I will say that it has evolved over, probably even in the period of the last four or five years.

MS. SLOAN: And I guess, Bob, I would just add that persistent functionality, we're addressing that in the context of Chapter 6.

CHAIR POWERS: Well, Chapter 6 is going to be fun.

MS. SLOAN: I think that really comes into play with the containment pressurization analysis. And, in fact, that's part of the systems described in Chapter 6. And I think we don't necessarily have the system engineers here that were involved with that testing program. But I guess what I'm hearing is we need to take that as an action and make sure that for the Chapter 6 presentation we have the right folks in the room to talk about the testing program and qualifications of the foils and dampers.

MR. TESFAYE: Yes. And I'd like to add, Dr. Powers, that the staff has asked significant number of questions regarding that issue in Chapter 6.

CHAIR POWERS: Good. Because I mean the problem is that when you test these rupture foils, you know you put pipe on one end and pipe in the other, put the foil in between. Delta p, it ruptures fine.

I put it in a room, put it a -- even if I put a nitrogen gas in there, yes, it fails. When I put in condensing hydrogen and steam, it doesn't fail because the steam is condensing out faster than the foil can respond. And so you just don't get the delta P that you need.

I mean,, the system was compartmentalized, it's that not compartmentalized. And the difficulty with all that is the steam condenses out because of boiling into a relative cool room here -- well the hydrogen that's left, you know, goes to the top of the room, up there it is and not just combustible but a detonable composition. And, you know, whatever in this world causes things to spontaneous denote will happen. And then you're struck into the question of okay, so why? And that becomes a very difficult question to ask because you're now putting dynamic loads on things that were never intended to get dynamic loads.

MEMBER SHACK: Are the mixing veins in the blowout panel redundant? That is, I mean since the mixing dampers are at least operator controlled?

DR. MARTIN: Well, there is a automatic system.

MEMBER SHACK: Right. But they could also be manually controlled.

DR. MARTIN: They also can be done manually and they're also, like I said, fail-open. And there's eight of them.

MEMBER SHACK: If only those worked, would you get enough convection to solve Dr. Powers' problem?

DR. MARTIN: We had an RAI, actually I think that came under 19, for what fracture of failures of the overall, both the dampers and the mixing foils. And I believe we got below 50 percent, possibly 25 percent of the assumed area was sufficient to get the kind of mixing that was necessary to mitigate hydrogen.

MEMBER SHACK: And what fraction of this area is blowout panel and mixing panel?

DR. MARTIN: Well, I guess I should explain a little better. The mixing dampers are actually regionally below the heavy floor that supports the RCS. And underneath that floor is the

IRWST. And in the wall above the IRWST and in between the heavy floor are these eight mixing dampers.

And then above the steam generators, above the equipment rooms are the rupture and convection ports.

So anyway, just to kind of keep us moving, I will be talking about the core melt stabilization in more detail here. So I'll just move on to -- and the role of the IRWST in just a moment.

Okay. Here in Section 19.2.2 identify the preventive severe accident design features addressing several event precursors described in the SECY-90-016. These include ATWS and mid-loop operation, station blackout, fire protection, et cetera. And kind of along the lines of what I was saying earlier with bypass issues, the detail in this section is cross referenced to other system description systems appearing in other FSAR chapters.

Okay. Now the next several slides I'll provide a description of the U.S. EPR's severe accident mitigation features. As we go through I will present this information within the context of an anticipated progress of a severe accident.

In this first slide what I'm illustrating you can focus here on the reactor pressure vessel.

There in the center I've attempted to draw a molten pool. Obviously, we've already gotten to the point where we've lost cooling, we've had considerable fuel damage, we've had fuel melt, we've had relocation down into the lower part of the core region.

The lower core support plate is considerable larger then, say, conventional BWRs. I forget the thickness, but it's larger.

And then surrounding the core within the core barrel is a heavy reflector. Maybe you've heard that from other discussions on the EPR. But the consequence of this heavy material in the core is we effectively create a crucible of such which holds a pool for some period of time until what we expect is that the failure of the heavy reflector causes the relocation from the core region into the lower plenum region. And the general expectation is that that metal melt would reside above the oxide melt. That there would be some separation --

CHAIR POWERS: There was a brilliant paper written by a truthfully perspicacious individual pointed out that that's not true.

DR. MARTIN: Well, not true and a possibly are two different things. You can't prove something not true, necessarily because the exception is always possible in rare events.

CHAIR POWERS: I believe that we now know exactly when the metal will be will less dense than the oxide. And in most circumstances the metal phase will be the more dense. And I believe they did this in the RASPLAV and MASCA programs in Russia validating a brilliant and perspicacious analysis that preceded the experiments by several years, the author remains unnamed, of course.

And so what happens when the metal comes down first?

DR. MARTIN: Well, that's okay too. Because this design has been made to accommodate that particular uncertainty. Nonetheless, the assumptions kind of going into some of our analytical tools have incorporated this particular assumption. Again, it's not that important because, as you'll see in a moment, our treatment of the ex-vessel phase of event, it culminates that kind of uncertainty. Nonetheless, we do get relocation in a severe accident or an expectation is that'd be relocation from the core region to the lower plenum.

As a matter of fact, I believe in the pre-application topical report I actually do address the different possible layering effect of oxides and metals, including a metal on top of oxide on top of metal type situation.

But nonetheless, one way or the other, you have significant relocation to the lower plenum. We can fail the reactor pressure vessel leading to a relocation into the reactor cavity.

In this illustration in the reactor activity is shaded with, I'd say, a beige color. That is there to represent the sacrificial concrete. Behind that layer of sacrificial concrete is a zirconia brick. The sacrificial concrete is engineered in a manner so that in its reaction with corium it conditions the melt. As a matter of fact, it does two things.

It provides a period of temporary accumulation, a time period to account for the uncertainties with the end vessel progression including that which you described with, say, the effects of different laying combinations of metal and oxide. Just as much as any kind of influence from the operator or even some unforeseen type of phenomena. Nonetheless, the sacrificial concrete provides a buffering, a time buffer allowing for the reactor cavity to collect as much as of the material as possible before the system allows it to progress to a long term state.

MEMBER ARMIJO: Is that a special concrete, high silica content or something that makes a different --

DR. MARTIN: Correct. The constituents high silica improves its spreadability.

MEMBER ARMIJO: Flowability?

DR. MARTIN: Flowability. And that is one of the goals here. Obviously one of the goals, again, is to make sure it's there for a few hours assuming a large relocation. You can also imagine if you don't get a very large relocation it takes longer to oblate the concrete. So its self-adjusting in that sense.

The zirconia backing is provided everywhere but the bottom center. There there is a basically engineered failure spot. It like what we call a melt gate. Above it is the melt plug.

After the melt has oblated through the 50 centimeters or so of concrete, it will reach that aluminum gate. Aluminum doesn't put much of a fight. And then once that hole opens up, the melt residing in the cavity in allowed to relocate into the transferred channel.

Okay. This slide covers a couple of phases.

The met in this case is now relocated from the reactor cavity, has flowed into the spreading compartment. In doing so it has severed a thermal fuse, we call it a cable effectively that's tensioned with what we call a passive flooding valve. And this valve in opening completes the circuit from the IRWST to a header residing underneath the spreading compartment. That header feeds many channels spanning the floor of the spreading compartment, underneath the spreading compartment. And then the water will fill that up. The hydrostatic head is such that faster a period of time, a number of minutes, it will fill up the spreading compartment in a manner that we can cool from both the bottom and from the top. And, of course, initially there will be some steaming. The flow rate is such that it's only like a 100 kilograms a second or so. This is basically engineered with a flow limiter. So there's not a significant concern of rapid steam expansion and containment over pressurization. Over time crusts will form.

One of the benefits of the conditioning process in the reactor cavity is that the oxides do become lighter than the metal and it lifts the oxides up. The oxides themselves, again, they crust, they also insulate the rest of the melt. And then in insulating inhibit steaming, at least briefly. As the room fills up eventually you saturate that compartment and then there is some steady state steaming. Its around between 11 and 15 kilograms a second based on our analyses of that process.

CHAIR POWERS: If you could come back to the first stages of this process.

Ah, you wanted to get by. You know that I'm not going to --

DR. MARTIN: Only because I have -- you made it harder to stay to the script.

CHAIR POWERS: You depict an oxide melt penetrating at what in the parlance of the thermohydrologists in this world is the focal point of the heat flux on the boundary spewing into a sacrificial concrete. And so you're going to have a very hot liquid coming onto a gas-evolving solid. You're going to have a tremendous production of aerosols at that point most of which will be heavily contaminated with radionuclides in what looks like a fairly tight cavity. What happens to those?

DR. MARTIN: Well, I mean obviously it'll be pressure driven. There are, as you said, it is tight. And I described in the FSAR the tortuous pathways that it takes to get into the broader containment region. There is some ductwork for cooling and it would serve as a leak point. But, again, as being a tortuous path, opportunities for settling are certainly there. And again, if you failed the reactor vessel, you can plow that stuff right back inside. And then there's certainly plenty of surfaces inside there.

Obviously, the closer you are to the mess, you know you're going to have the biggest effect and it will be reduced, you know maybe r-squared, somewhat, as you get farther away from the mess.

CHAIR POWERS: It really it is crucial in this design that you be depressurized at this stage in the accident?

DR. MARTIN: It is crucial, absolutely. And certainly that's reflected in the SECY-93-087 that all these designs incorporate a primary depressurization system, or what do the other competitors call them? Automatic pressurization systems, and what have you. But that is obviously the primary purpose of such a feature to prevent high pressure melt ejection or even a lesser than high pressure melt ejection.

But MAAP does incorporate some models that provide for pressure driven transport of radionuclides that is there. And it, again, also has the models for settling out.

CHAIR POWERS: Have you looked at the situation of a polar failure?

DR. MARTIN: The what failure?

CHAIR POWERS: Polar failure? On the pole rather than on the lateral edge with a pressurized vessel?

DR. MARTIN: I think we had a question on a spallation.

CHAIR POWERS: That's not the one I was worried about.

DR. MARTIN: No. Launching. I mean, the launching is a question that I believe has to be addressed with the SECY-93-087. I'm sure I've written something in here about that issue.

Actually, I believe Dave Gerlits, who is listening on the phone in theory, has performed the phenomenological evaluation, specifically regarding the launching of a --

CHAIR POWERS: Yes. The depressure -- how depressurized do we have to be before we start doing grievous things. Of course, launching the vessel is a picturesque description, but the more troublesome thing is ripping out the penetrations.

DR. MARTIN: Sure. Well, to compliment what Dave Gerlits did for the phenomenological evaluations performed with the work in 19.1 for the PRA effort, we took the results from our analysis. Now we were relatively conservative in our treatment of the depressurization process. We assumed a degree of uncertainty in timing of opening up those primary depressurization valves. In fact, the rule that will be provided to the operator would be to open them up immediately on T-core outlet. But in our assumptions in doing our analysis we delayed it by as much as a couple of hours. This was an uncertainty parameter which I'll talk about in a little bit. And then on top of that we only assume done train. In fact, we have two trains.

So even in a conservative analysis we showed in our results that we get to in the worst scenarios down to between 10 and 12 bar. Now looking at the results, obviously, I wanted to see us being 1 or 2 bar, you know. But there was work done, I believe a Sandia, maybe colleagues of yours, that identify kind of a threshold of no concern around ten. And so I referenced that.

Clearly we have cases in what I would say a conservative analysis where we're just above ten.

I'd prefer that we be below ten. But as we sharpen the pencil, certainly we can get down I think below ten. And as we go into the detail design, go into the accident management realm which of course we have questions on, we will sharpen the pencil in those areas and I think we will find that we don't have a problem with regard to that issue.

CHAIR POWERS: I am vaguely familiar your cite 400 psi, a little marginal on that. But my recollection is that was born from experiments done in specific cavity configurations and in particular for relatively open cavity configurations a la Zion, Surry, whatnot. And I don't know what the authors would have to say about tight configurations, because I don't believe they ever did experiments on what I would call a tight vessel with a small cavity.

So the question comes up is: Is there a threshold that they define applicable to this particular vessel and cavity configuration?

DR. MARTIN: Obviously, I can't answer without going back and studying that particular. One thing you can think of, it does open up a little bit. There is insulation, of course, all around the reactor vessel which is sizeable. The expectation would be in a case like this that would probably rip to shreds. And it would, in theory, open up but it would also capture a lot of the mess on its way. And it would not necessarily be allowed to flow out.

CHAIR POWERS: And again, that's not the question I'm worried about. It's the recoil in the vessel ripping penetrations out and creating a direct leak to the outside.

DR. MARTIN: Yes.

CHAIR POWERS: And I believe the experimenters did experiments for a cavity with insulation in the vessel to cavity-wall gap and found that what happened in contrast to what was expected, which was that the insulation would be stripped of and just pushed up into the containment building, that it caught on various things and jammed up.

DR. MARTIN: Yes.

CHAIR POWERS: And though they had -- it was certainly not leak-tight, it certainly created a substantial pressure across there.

DR. MARTIN: Okay. Well, I'm not an expert on all of that.

CHAIR POWERS: Neither am I.

DR. MARTIN: You know, local loads or other things might also be relevant in that kind of questioning. And other areas may also be relevant to the discussion.

All right.

MEMBER SHACK: Just coming back to that for a second. You have the cast iron cooling system underneath there. And as I understand it, the sacrificial material goes. And so you have the corium sitting on the cast iron and you're confident that this is going to work?

DR. MARTIN: That's correct. Yes. We have, I believe it's ten centimeters of the sacrificial concrete that has been engineered on that. There's been some evaluation.

Basically that is there to buffer to provide enough time that we can get fully developed flow into the cooling channel structure. And then, you know we certainly have analyzed it --

MEMBER SHACK: To limit that flow, right? I mean, that's --

DR. MARTIN: The flow's limited to, yes, a 100 kilograms a second.

Now we have done tests. We've done basically single channel tests at our offices in Urlangen. Basically putting looking at flow going through the equivalent channel and then, of course, increase the heat flux to something equivalent --

actually equivalent and beyond to what we would expect in this situation. So we do have a considerable amount of confidence that comes from this test program.

Again, it's described primarily in the pre-application topical report. I believe I do briefly mention it in this report because it established a criteria for us to measure the effectiveness of cooling. So even though there is not a explicit criteria, say in the SECY-93-087, we derived a criteria that we would then use to demonstrate the performance of the cooling structure. And then, of course, we followed with conduction analysis, the WALTER code which I'll talk about in a little bit.

MEMBER ARMIJO: Why did you pick cast iron for that component? Anything special about it?

MEMBER SHACK: A nice Victorian touch, I thought.

DR. MARTIN: We have a lot of experience with cast iron. We all go camping and it seems to be very effective at containing my steak, or whatever I'm cooking.

CHAIR POWERS: But it's not so good at containing materials that have a substantial amount of unoxidized zirconium in it.

DR. MARTIN: And we expect a lot of oxidation of zirconium when we get to this point of the game. Certainly lots of opportunities to oxidize zirconium

MEMBER ARMIJO: There must have been some basis for the selection of that particular material. I just wanted to know what it was.

DR. MARTIN: You know, I would just speculate. I assume it's relatively easy to forge. It's a large single component.

CHAIR POWERS: Cheap and highly thermally conductive agent.

DR. MARTIN: What's that?

CHAIR POWERS: Cheap and highly thermally conductive.

DR. MARTIN: Yes.

MS. SLOAN: I think what I would suggest is we follow-up then to get the why question.

CHAIR POWERS: Yes.

MS. SLOAN: That's what I'm hearing; why rather than speculate.

CHAIR POWERS: Right.

MS. SLOAN: I think we just need to take that as a follow-up action.

CHAIR POWERS: And then you can explain to me what happens when it gets hit with a zirconium-rich melt.

DR. MARTIN: Okay. Okay. And this slide illustrates the severe accident heat removal system. This system includes that phase I just talked about with the passive cooling system. Again, it's with a name like severe accident heat removal, it sounds like an active. But we fold in this passive phase of heat removal.

The piping illustrates here a couple of modes. One, of course, was the passive flood the orange.

As I said earlier, we do expect at some point the pool above the spreading area to saturate, this was steam. Steam, of course, does pressurize the containment. And we have a spray mode. Now these sprays are nonsafety-related sprays. These are sprays designed for severe accident. And as we'll get into eventually with Chapter 6, you know we do not have a spray system to address design basis analysis. But we do have a spray system to address severe accident.

It, of course, helps mitigate the pressure, hold the pressurization. It also helps scrub out fission products.

The layout of containment is such that the spray water will drain down. Everything drains into the IRWST. And so you have a closed-loop system with regard to the cooling water.

Again, here's the spray line. The water will spray down. You will get some condensation in the coalescence. And everything leads right back down to here.

In the long term when operators have decided that it's time to address recovery, remediation, decommissioning and exactly what that time is, is yet to be determined. For the U.S. EPR it may be 24 hours, or it may be beyond that. There is a active flooding stage, in which case "active" meaning an active pump that would circulate, again, from the IRWST through the same channel where the passive flow is and then into the spreading compartment.

And it'll illustrate better here it will flood the spreading compartment, a chimney that resides above it, but also because there's a hole here it will flood up into the reactor pressure vessel area and recovery any remaining melt. It also provides another way to kind of capture fission products, particularly anything that remains in settled areas, as well as anything that might come out of the spray system.

CHAIR POWERS: Let me ask you a question about your sprays. I've talked to my friends and neighbors about the EPR. They're intensely interested, of course. Because New Mexico is so close to Maryland, no doubt, they ask me gee, the spray header in the U.S. EPR is not a safety-grade system. But the sprays in Finland EPR are. And the spray in Flammenville in France will be. How come it's not in the U.S. EPR?

DR. MARTIN: That stems from different definitions of safety-grade. We are more black and white in this country and the countries are --

MS. SLOAN: It, in part, goes to how you treat severe accident mitigation systems and how you classify those systems differently in the U.S. than we do in other regulatory environments. They're not credited to perform a safety function in the Chapter analyses, and that's essentially the criteria you would use in the U.S. to do the classification.

DR. MARTIN: Moving on. That kind of concludes the design description. But I expected it to be the longest section of the discussion.

CHAIR POWERS: We have tried to disabuse you.

MS. SLOAN: I don't think I could tell.

DR. MARTIN: You know, I've had Ed and Annmarie cornered for a day doing this day. I have no problem going on. But Sandra and Brain, they'd take issue I spend too much time.

MEMBER SHACK: Which of these systems ends up in the RAP program? All of them?

DR. MARTIN: No. Well, the RAP list has been modified. I provided some input on RAP in my opinions. But it does not come down to my decision.

MS. SLOAN: We don't the answer.

DR. MARTIN: Right. But there are components of this that I would say it's the active components of the SAHRS fall underneath that. I would certainly recommend. Again, I don't have a say that the passive elements do not appear on this. I don't think there's precedent for that.

MS. SLOAN: And we'll have to follow-up and make sure you have a copy of the RAP list.

MEMBER SHACK: Well, it may even be in the RAP list. I just don't remember it.

DR. MARTIN: There's update to that.

MEMBER SHACK: I can't remember what the RAP list looks like off the top of my head.

CHAIR POWERS: Oh, Bill, come on.

MEMBER SHACK: But John can.

CHAIR POWERS: You have some starters to maintain yours.

MEMBER SHACK: I'm not even going to try.

DR. MARTIN: Okay. In this one, I kind of as a transition slide getting to the analytical methods, I put some motherhood statements to kind of address our goals in moving forward with our analytical methods. You know. motherhood statements, sufficient technical qualities, address the goals appearing in regulatory documents with emphasis on 24 hours or more likely severe accidents.

So, let me move on to this illustration of what we're using to perform severe accident valuation.

The centerpiece of our analytical tools is, as I've said, the MAAP code, MAAP Version 4.07 was effectively commissioned with models to address EPR in general, U.S. EPRs specifically. And in a case or two this expanded on the ex-vessel modeling that was necessary for EPRs, although the older versions of MAAP did have some ex-vessel capability. But we needed something to address multiple pools. We needed something to address the influence on the inside of the heavy reflector. We needed more modeling capability in the containment.

We have, as you'll see in the second bullet, a model with 27 control volumes. We also keep a model with 11 control volumes now for other studies.

So we have our version. MAAP 4.07 is now the latest, greatest issue provided by EPRI to the MAAP users group community. So our models are available to members of EPRI.

Along with that we have a couple of other codes that we use to perform supplemental analysis in areas where MAAP is deficient or where we wanted to go off and do studies that related to questions that we had about severe accident phenomena.

These are the WALTER code, which is an in-house code. It is a one dimensional heat conduction code with phase change, a solid to liquid, liquid to solid. We used that in a couple different areas.

And then we had the METSPREAD code, which is an NRC-sponsored code. I believe it was developed at Argonne addressing spreading of corium. And corium mixtures with, say, concrete.

So those are the suite of codes that we use primarily.

The evaluation methodology that I was working with or working towards, I tried to model it off, basically, the Reg Guide 1.203, even though this is a Reg Guide developed for design basis safety analysis, it certainly -- I of course with my own background in design basis safety analysis I endorse its approach and wanted to emulate it to some extent. Obviously, it's a little more complicated with the severe accident so it gets a unique flavor with this application.

So I have what I term a three-fold approach to the safety issue resolution beginning with the identification of what I termed the relevant scenarios or this is where I tried to define what more likely events, more likely scenarios, which it appears multiple times in the regulatory documents.

CHAIR POWERS: Now, I think this just gets you into a conundrum here. Because what we're really interested is the risk-dominant and not the frequency-dominant scenarios. And so you get locked into this CDF and it leaves you neglecting those things that have low frequency, but they're the high consequences like bypass accidents and things.

DR. MARTIN: Well, and in my topical report I try to address that. I try to draw a line in the sand where I say that we examined cutsets or event categories that span, I believe, 90 percent of the domain of severe accidents event precursors.

CHAIR POWERS: Yes, but you're still in CDF space here.

DR. MARTIN: I'm still in CDF space. Again, we have expectation to define more likely scenarios. So this is how I went about it. And it is Level 1 core damage frequency-informed evaluation.

CHAIR POWERS: As I have characterized it's CDF-informed during normal operation events.

DR. MARTIN: Well, you know have to draw the line somewhere. I mean, we can take remote events, on top of remote events and remote events and you could find something that's going to cause -- again, your low frequency high consequence. And that's a separate element of Chapter 19. We've certainly had questions on that.

When I say "more likely," I'm excluding the very low frequency type events. So that's where I'd begin all this work. So, that is a key assumption, and it's certainly open to scrutiny.

so I've identified a set of relevant scenarios. I'll get into that a little bit. I focus on, like I said, classes and try to capture -- maybe I'm getting ahead of myself a little bit. But since you asked, I'll go into it a little bit.

I tried to take this classes of events and collapse them down into kind of a manageable set. And then incorporate assumptions into this set, elements that might characterize bounding conditions of the class itself. So I've made an attempt at that.

I also carry along a few extra cases which I don't advertise so much, to kind of accommodate changes, the review process, whatever. Just to kind of protect myself from the uncertainty of the process of going through this type of review.

So I have this set. On top of that I have an uncertainty analysis. And this uncertainty analysis tries to examine all those elements that are of interest and specified in the SECY-93-087. Again, listed there, there's a same list before.

And then when I look at that going there are going to be holes, there's going to questions just like you have, or Ed, or Annmarie, or who. And then I start targeting the holes. And that's the last phase of it to compliment the other two.

So maybe -- sorry.

CHAIR POWERS: Maybe just to understand better, I mean one class of events that always comes promptly to mind with this particular unit as we get into the severe accident analysis and all the material that you covered earlier is suppose we have an earthquake as the initiating event, how much does that effect the progression that you outlined for us before?

DR. MARTIN: Well, I don't get to what causes the break or what causes the loss of a component. You know, if it's an earthquake what I would begin with is I've lost off-site power. Obviously, that's a big one as you maybe recall from our February meeting. Loss of electrical loads, station blackout is a key contributor to our PRA numbers. So that knocks out certain things. And then we have assumptions along the lines of loss of the backups, loss of anything that might lead to loss of core cooling, effectively. You know, whether it's an additional break; you know multiple failure obviously lead to a severe accident.

So I don't know. It may not answer your question with regard to earthquake, but I got to begin with --

CHAIR POWERS: Yes, it does.

DR. MARTIN: -- a loss of a component, not what caused the loss of the component.

CHAIR POWERS: But I mean in this case the initiating event has, presumably, some impact on all this structure that you've got for handling this core melt. And so it initiates the event and now the melt comes down to the lower plenum, and now what does it do when the carbon steel plate has now fallen to one side and the flow paths that you've developed have been ruptured?

DR. MARTIN: Well, I think, again you can apply layers of failures. And layers of failures get more and more remote as you try to find that Achilles' heel. You know, we don't assume a unique failure of the core plate, and I think that matters because we'd get relocation to the lower plenum and you wouldn't necessarily sit there on top of -- you know, I've had a pool maybe on top of the plate and --

CHAIR POWERS: You see, the trouble I'm having is you tell, okay, I'm going to look at things where the core damage frequency is greater than 10 to the minus 8. And I have a RCOLA coming to me on a site that I'm sure has 10 to the minus 6 earthquake core damage frequency, since every place has a 10 to the minus 6 core damage frequency due to earthquake.

DR. MARTIN: Right.

CHAIR POWERS: So, I mean it's nontrivial compared to your threshold. And I don't know how that system, and they're not two things here. The initiating event brings the damage to the melt relocation system simultaneously. And I don't know how sensitive it is to that sort of thing.

DR. MARTIN: Well, I mean the question certainly -- it's an obvious question whenever you're dealing with the broad uncertainty that's there with complex system. It's not a unique to U.S. EPR. Certainly not unique to advanced reactors. Not unique to nuclear power, even. So, yes, you can combine such thing, such uncertainties.

I think this industry does a great job by incorporating PRA. I think we get a much better look at this kind of question. As a matter of fact because we talk about it, we ask more questions.

So, I mean obviously I'm being a little philosophical here. But, you know, that's where we're at with those kind of questions. It becomes a bit philosophical where you draw the line.

CHAIR POWERS: Well, you drew the line.

DR. MARTIN: We take a pessimistic approach to these kind of analyses. Again, I used the PRA information to the best of my ability. I do make some assumptions. I assume for these deterministic studies that our features set -- you know, most of our features for severe accidents work, you know most important being the pumps on the SARS, you know.

My goal here is to demonstrate that the concept works. And, of course, your job is to review and see if there are vulnerabilities or limitations. And at some point, you can find something that you can come up with a scenario.

CHAIR POWERS: Yes, but I wasn't imaginative. And I drew it within your boundaries.

DR. MARTIN: Well, I don't think you have to be very imaginative to get to that point. I mean, you can imagine, you know a meteorite, an asteroid --

CHAIR POWERS: But that would be outside of your boundary. I drew it within your boundary.

MS. SLOAN: I think I've captured the comment. I don't know how much further you want us to go with the discussion, Dr. Powers.

DR. MARTIN: Yes. Well, I would say --

CHAIR POWERS: Not any further. I mean, there's no point in taking it even further because we haven't got anything here.

DR. MARTIN: Okay. This slide's on the relevant scenarios. And I've kind went, like I said in the previous slide, I got ahead of myself a little bit in describing what we do. PRA Level 1-informed. A combination of the many scenarios classes. And the list of classes appear in actually Chapter 19 Section

1.

And I went through an evaluation process to identify specific core and plant damage end states that emphasize the reactor pressure, reactor system pressure, reactor coolant system pressure at the onset of core damage and also where the heat was going at the time. You know, do I have, say, a natural circulation loop going out into the loops themselves or is it mostly heat contained, a pop could impact that. Those I felt were basically number one and two when it came to categorizing my relevant scenarios. Obviously, the initiating event whether it was a LOCA, whether it's a loss of heat sink were all incorporated into that decision making process.

And in the end I have a summary table that lists the probability of a given risk-relevant event type leading to a particular core plant damage end state.

Next slide provides a very high level description of these events. The LOOP TR is a loss of heat sink, a loss of off-site power event with expected the bleed valves are not open, so the RCS is high pressure at the time of core damage. In fact, I have to assume a delay that the operators do not follow the rules there of opening up the primary depressurization valves. So there is even a human element to the assumptions which, I would say, wouldn't necessarily be required in this kind of activity but it was really necessary to get us to this type of category.

Nonetheless, you see lists there. And you'll see LOCA, you'll see loss of off-site power, loss of heat sink without good power so that there was a pump RCP on. So I also carry a couple of others, a steam line break, I carry a large break LOCA. Again, just in case I need additional insights to these events.

That, gain, defines our best estimate calcs.

Under the cornerstone of all our evaluations hinges on uncertainty analysis. Uncertainty analysis is in the tradition of Reg Guide 1.203 or the co-scaling applicability uncertainty methodology. The bottom-up, top-down type approach.

I went through -- we didn't do a PIRT, say, phenomenological identification and rating table process. However, this kind of activity has been done with EPR in mind. In Europe it's been done certainly for conventional PWRs. I had that information and I kind of composite together to identify phenomenological classes, as you see here in the first column, the left column in red. And I've tried to list them, more or less, in even progression order. You know, there could be an exception or two, but you'd certainly you'd understand. Thermal-hydraulic and fuel rod degradation, core melt progression in vessel, on and on.

The next step was to look at those classes and kind of break that down into what I viewed as much as what I could glean from literature. I do have some experience, so my judgment probably colors it somewhat. But stored energy to decay heat, obviously metal water reaction are important early on. On and on, identified several associated problems.

And then the next step was to look at what was in the code that would reflect an influence on those phenomena. And so I broke it down even further, identified particular code inputs that which would enact some kid of influence on my simulation event progression. So, that is what the right hand column is listing there.

I came down to what I felt were 27 unique code inputs influencing the 19 or so or 15 or 19 or so phenomena classes.

Okay. So what do I do with that? Well,

allow myself to be recelebrated with the expectation of SECY-93-087 looking for deterministic engineering analysis and judgment complemented by PRA. The uncertainty analysis that I have developed with a lot of help from Mike, I should say, allows for broad consideration of uncertainty. And I'm looking at 27 different parameters and these influences on many phenomena.

I also include in the uncertainty analysis a weighting on the relevant scenarios themselves. And that, of course, is Level 1 informed. It does incorporate some engineering judgment. So it's certainly open to that kind of qualitative scrutiny.

And then, of course, I had to go off and do a review for what would be the uncertainty domain of those 27 parameters. And, actually I had a lot of help because Fauske and Associates has done a lot of this work. But they're not the only ones. As you know, as your friends down the hall at Sandia have done similar activity with MELCOR. And I also am familiar with work by Randy Gauntt in this area. I know he's focused a little bit on hydrogen in particular. And so I've talked to him a little bit. But, you know, I use the contacts, use the broader state of the art understanding in this field incorporated it into our methodology and have quantified, to the best of my ability, the uncertainty domain for the U.S. EPR.

The process itself, we apply a non-parametric approach. I'm not sure how much you've gotten into the work and the realistic large break LOCA, but it is a methodology statistical approach that what we're implying is similar to that which is applied in the large break LOCA analysis, either Mote-Carlo-like simulations with many sampled cases. These are effective experiment, numerical experiments done many times by sampling the individual parameters that have been identified for treatment within the uncertainty analysis.

CHAIR POWERS: The analysis that you're doing here assumes that all your parameters are independent.

DR. MARTIN: They're all independent, correct.

CHAIR POWERS: And why should I assume that?

DR. MARTIN: You know, you asked me that question last September when I was --

CHAIR POWERS: I didn't get it answered then either.

DR. MARTIN: Although your example was a little bit better in September because you used the metal-water example. Because the work of Cathcart Powell identified two uncertainty parameters. Basically it's an exponential function. There's a constant on the front and then exponential uncertainty. And you pointed out that there was a correlation. And I did ignore that.

And I think my statement there is, it is an inherent assumption in approach.

CHAIR POWERS: And what it strongly effects is your bottom line there that says, okay, I've sampled 95 percent of the range. True only when they're there independent. As soon as there was correlation between them, now you no longer can say that. In fact, you've narrowed it substantially. If there's any correlation --

DR. MARTIN: Well, right, it gets narrowed. And part of my answer then is what it would be now. Generally by -- and it's not a hard and fast rule, but regarding the uncertainty ranges the coupling of correlation tends to broaden the overall uncertainty and move out that tolerance limit.

You know, I think you get a higher level of confidence the more parameters you're looking at.

Particularly, we have 27, we had like 30 or in the LOCA. The more parameters you use and the more you follow that rule of thumb, I think you're okay. Again --

CHAIR POWERS: So I would like to have some demonstration that that rule of thumb has any -- I will agree with you it seems plausible.

DR. MARTIN: Right.

CHAIR POWERS: I don't agree that I can demonstrate that in any kind of persuasive sense right now. I mean I don't argue with your argue with your plausibility. But I do argue --

DR. MARTIN: Right. There is an exception to every rule. It is one of those rules that you could probably find an exception to. Even in design basis space the regulations don't say 95. They say a high probability of meeting criteria.

So I would think and beyond design basis we probably have a little bit more liberty to stand behind that kind of -- our own definition in this particular case.

So, yes, you found me out. I forgot about September you brought that same question up.

Fifty-nine cases is the magic number with a unvarying assumption. As a matter of fact, I'm in the camp where it is always the case but that'll be something you'll probably get into more when you talk more about realistic LOCA. All I claim really in the FSAR and in our methodology is that it's a good method estimate of tolerance limits. And I try not to make a claim behind I have here.

But I don't believe I've used that language in FSAR, but I could be -- I was trying to be sensitive to that at the time. But I'm human.

Here's a list of selected uncertainty analysis parameters. I've highlighted several parameters impacting hydrogen uncertainty and core debris coolability uncertainty. As I said before, I had a lot of help there from Fauske and from the MELCOR team at Sandia in kind of picking these numbers here.

One thing is notable, however. Is that the 10 CFR 5044 rules regarding combustible gas say I have to look 100 percent metal water reaction with regard to hydrogen generation. The codes tried to best estimate, as well as they can with today's state of the air. As such, if you perform a best estimate analysis, you don't get a 100 percent. So I'm really not familiar what other people do, but what I chose to do was buy us parameters that I thought would have the greatest influence on the hydrogen generation.

So, for example, if you look at the first one, it's a water reaction multiplier. You would think best estimate would be one. A multiplier of one. You can see I used --

CHAIR POWERS: No you wouldn't.

DR. MARTIN: If someone did a best estimate model, you would hope the multiplier was one.

CHAIR POWERS: No, absolutely not. I mean, you're trying to compensate here for not only a zirconium reaction with steam, but also a stainless steel reaction with steam.

DR. MARTIN: I think it's a model that's applied to both. True.

CHAIR POWERS: I mean it has to be greater than one.

DR. MARTIN: So, again, I'm trying to get 100 percent. I wasn't getting that. So you can see, 1.5 is above what a best estimate model would be. Now, you know Fauske, I believe they don't use 1.5. They'll say a low value, I believe, of one. And then a high value might be 1.5 or something like that.

I shifted that, obviously, to get more hydrogen.

CHAIR POWERS: And the problem that we

have with that, not so much with that one, but with many of these is that you said yes there's a range, but I don't know what that range really ought to be. And the way you sample, those are kind of fixed ranges there.

DR. MARTIN: They're fixed ranges, that is true. So the integrity analysis with these assumptions.

CHAIR POWERS: And the other problem that you have, it seems to me with this, is for instance take particularly the debris size in the lower plenum. What you have is a single particle sized model until you pick the particle size there. But, in fact, we know it's a distribution of particles.

DR. MARTIN: Right.

CHAIR POWERS: And there's no reason that that behaves at all --

DR. MARTIN: Right.

CHAIR POWERS: In fact, we know absolutely that mixed debris tends to behave like the smallest debris particle in there. And so your range is in fact, even when you were in the coolable direction, where it probably should not be.

DR. MARTIN: Well, you know, the process to come up these numbers is not just, you know -- and particularly in the case of Fauske and Associates. They have studied these, you know, their code sensitivity to the many tests that are available in the severe accidents experimental domain. I think Fauske's like Sandia, you know has had ample access to the best that's out there. And I think we all acknowledge it. You know, they are leaders in the industries on this stuff.

So that's the pedigree. It comes back to that expertise and that empirical evidence of how the codes perform against that empirical evidence.

Granted, they themselves acknowledge that one number doesn't do it by itself for all tests. That's why they provide both the high and the low.

So there is a method to the madness. You know, it's logical and we're just following on by using kind of contemporary uncertainty analysis methods to get to our results. But at a proper review of this process, again, has to look from bottom up. It also has to consider it from top down.

The bottom up being breaking it down like this. This is the right way to do it. Breaking it down to the phenomena, looking at how the codes respond to the sensitivity in these particular parameters. And then also where those parameters come from. That comes from integral tests and how the codes respond there. And that's how you do an uncertainty analysis today. And that has been captured, I think, in the Reg Guide 1.203, which is only five years old now. But that's where we're all moving to, and it's the right approach to doing both safety analysis and, in this case, severe accident analysis.

And all our competitors should follow our lead.

CHAIR POWERS: And problems you run into are things like corium friction coefficient, and nobody knows what the corium friction coefficient it is. It's a parameter in the code to compensate for physics they don't care to model.

DR. MARTIN: Right.

CHAIR POWERS: And so the only recourse one has with that is to run against some test and vary it. And, unfortunately, there are 15 other parameters in the code. And so you don't have a unique set.

DR. MARTIN: Right.

CHAIR POWERS: And consequently corium friction coefficient has an obscure correlation with the other core. And so ipso facto is not uncorrelated.

DR. MARTIN: Right. Well --

CHAIR POWERS: And no one knows what the appropriate range is. I mean, you take in a factor of 100, it looks very impressive, you know, huge range. But in fact the real range on what that corium friction coefficient is could be much larger.

DR. MARTIN: Right.

CHAIR POWERS: Or it could be biased in the region which actually turns out to be worst in these calculation. We simply don't know and nobody can know because you can never measure the corium friction coefficient.

DR. MARTIN: One thing I did as kind of a sanity check. And I don't think I've incorporated it in our discussions with the NRC. Is what also kind of becoming best practices in best estimate analysis is importance analysis or sensitivity analysis that incorporates the results from this kind of analysis and effectively you can use that as data effectively to identify the importance of the parameters that are being sampled.

Now, it is a function of the -- well the importance of that particular -- real importance of an individual parameter, but it is also a function of the domain chosen. So you can take a very important parameter at a water reaction site, if you held it constant, you wouldn't see a sensitivity. Meaning that you could take even in the case of, say, what you just mentioned, the corium friction coefficient and its two orders of magnitude. Obviously, it's a very broad sample range. That may or may not show up in the sensitivity analysis.

So but it is a way that allows you to kind of close the loop with that decision making process. Now in that particular case, corium friction coefficient I don't believe come up even though it has two orders of magnitude sample range. But things that do come up are metal water reaction, the art of cladding breakout temperature and fuel melt temperature. You know, it has a big influence on both the hydrogen and core debris coolability. These things do pop out.

Now I will also say that severe accident analysis, and there's a lot of uncertainty as I think everyone would agree, the important elements that come out of the analysis, this particular analysis, aren't quite as dominant as, say, in LOCA where very clear break size is really important. Heat transfer, post-CHF heat transfer, these things are very dominant in the progression of a LOCA.

Severe accident it's a little bit grayer and there are more things that kind of play a role. But nonetheless, you can get a lot of insight and kind of close a loop on methodology development.

CHAIR POWERS: I think I know what you've done, I'm not absolutely certain. I assume what you've done is when you say I've come up with these various parameters that you considered uncertain that you have subsequently looked at the correlation of those parametric values with figures of merit that you select --

DR. MARTIN: Correct. Exactly.

CHAIR POWERS: And I suspect that you've used a Pearson-type correlation model. And so you've looked at the linearity in linear correlation between results and parameters values in a system that is, if anything, that is nonlinear. And I think it would be very useful to get those results.

I'd like to know why you chose Pearson correlation coefficient --

DR. MARTIN: Spearman is also used. I wanted to use something --

CHAIR POWERS: Spearman is identical to Pearson.

DR. MARTIN: Right. And these are --

CHAIR POWERS: Kendal Tau, BKR, things like that. BKR is used for when things that are not very correlated. But Kendal Tau is nice because it will reveal nonlinear correlations with the result.

DR. MARTIN: Yes. I focused on, again, because you can almost infer because I used large ranges and uniform distributions that what really matters most is variance -- you know the tolerance limits of the figures of merit relative to the changes being incorporated into the analysis. So I tried to quantify what those were.

The ranking process are just strictly that. They're ranking and they're not given in terms of, say, hydrogen concentrations. So that's why I avoided the ranking methods for some of it.

But anyway, it is in the NURETH-13 proceedings. And we can certainly provide that if you're interested.

CHAIR POWERS: Well, I think it's very revealing. I find it one of the best code debugging tools that I've got. And when you see a parameter being important that you think ought not be important you --

DR. MARTIN: Exactly.

CHAIR POWERS: -- the first thing to check is your code and not to try to understand the physics behind a mysterious correlation.

DR. MARTIN: Exactly.

CHAIR POWERS: So, yes, it would be useful to see those results. And where you see either strong positive or strong negative parameters correlation and then you ask the question did I make the range too wide, not wide enough; things like that.

DR. MARTIN: Yes. It's a good exercise. And, again, I expect you all to make our competitors do the same thing.

CHAIR POWERS: I don't think people are getting very active there yet.

DR. MARTIN: I think so.

CHAIR POWERS: But I continue to worry about claims that you've samples 95 percent of the parameter range when in fact you have not looked at correlation in a realistic fashion at all, and yet it's open to because you're using Monte-Carlo instead of something really dumb like limited lat and hyper-cube sampling. You can actually take the correlation and make it one of your uncertain parameters where you think that the correlation exists, or could exist.

DR. MARTIN: We can incorporate correlation in this. It was a conscious decision made a long time ago that we would --

CHAIR POWERS: Yes, and fairly common. I mean, most people do. But you choose parameters, your parametric choices are, in some cases physical, in some cases artefacts of the code. And when you choose physical parameters, then you can choose them in such a fashion that there's a high chance that they're approximately uncorrelated. When you choose these parameters that some code analyst has chosen to hide a lot of physics in a simple parameter, they're making them uncorrelated is a -- I mean, you can just never argue that because nobody knows -- they can't be measured, nobody knows what they are. They just match a particular experiment done by some particular group on particular occasion. And you don't know what the correlations are.

DR. MARTIN: Yes.

CHAIR POWERS: And it reflects things.

Now I'm dying to see where we're distributing deuterium around here.

DR. MARTIN: Yes, this was unfortunate editing. It was not the way I shipped it out. It was not a superscript, it was a subscript.

But anyway, I wanted to kind of just go through our results. Of course, the FSAR discussed what we got.

With regard to this slide, combustible gas control system evaluation, our analysis met the following criteria. And this comes from the SECY, so I'm kind of repeating.

First off, that the hydrogen was well distributed in the containment and removed for the PARVs for load minimization.

This was evaluated by looking at, again, we had a 27 node model and then looked at how the ranges of individual compartments varied against each other. And we're looking for a relatively tight band. And so, you know, they don't all lay on top of each other but there is a good trend in all the compartments.

This next item is, you know, you're probably most familiar with the 10 percent by volume concern. Again, the PARVs do their job and keep us well underneath the 10 percent limit.

CHAIR POWERS: When the PARV does its job, it is in fact burning hydrogen. And it must surely get locally quite hot on that PARV. If I have things like particulate cesium iodide following through this hot zone along with the hydrogen, do I convert the cesium iodide into iodine gas?

DR. MARTIN: I can't answer that.

CHAIR POWERS: It seems like I would.

DR. MARTIN: It's certainly plausible.

MS. SLOAN: We can take as an action.

DR. MARTIN: Yes, you know, you're burning and you're in an environment where you could put an O_2 on probably a lot of things.

CHAIR POWERS: Isn't it true that Nelson did some hydrogen combustion events, experiments with -- I know nobody's suspended cesium iodide, but he distributed cesium iodide in his cell and absorbed iodine gas.

DR. MARTIN: I'm not familiar with the work by Nelson. But we can look it up.

All right. Well, that's a good question, and it kind of relates back to the early discussion about RIAs that Annmarie had provided.

Okay. Moving on. The next one relates to reducing hydrogen concentrations below 4 percent by 12 hours.

CHAIR POWERS: Were you homogeneously combustible during that 12 hours?

DR. MARTIN: Excuse me?

CHAIR POWERS: You go from a maximum of 10 percent down to 4 percent. That's over the course of

12 hours. So you're in the combustible regime for 12 hours roughly. And the probability of not getting a spark or an ignition event, I mean we know from TMI that there are spontaneous events are at least a non-zero probability over a 12 hour period. That's only true if you're not steam-inerted. You have spray system which could cause you to be de-inerted in there.

DR. MARTIN: Right.

CHAIR POWERS: So basically what I'm asking you is did your PARVs work in the sense that they perverted a global deflagration, which you tell me in your next slide in your containment, and I'm not surprised by that. Nevertheless, a global hydrogen combustion event is non-trivial. And again we know from TMI that that does damage internal equipment that we might be relying on for recovery post-accident safety measures and things like that.

DR. MARTIN: Could be.

CHAIR POWERS: And so the question I'm really posing to you is where you combustible over that entire 12 hours?

DR. MARTIN: And the answer is no.

CHAIR POWERS: No?

DR. MARTIN: We're not combustible.

CHAIR POWERS: That means you did not activate your sprays?

DR. MARTIN: No, we did not activate. As a matter of fact, it's not a requirement in the U.S. but one of the reasons for the 12 hours is to demonstrate that we can accomplish these goals passively.

CHAIR POWERS: But then the question is what is the chance that the operators would observe your encyclical against activating the sprays over a 12 period?

DR. MARTIN: Of course, we have to look at that too. And I am co-author to a paper appearing in June on the subject at ICAP. So we've done some work on that as well. And basically come to the conclusion is that while reducing the inerting to some extent does occur, it does not create a significant impact to the situation that we have a combustible problem.

CHAIR POWERS: That's going to be a very interesting paper. I mean, your spray is extremely effective at de-inerting you.

DR. MARTIN: Well, it goes to both how much hydrogen producing. It considers the performance of the PARVs. And it doesn't necessarily take 12 hours to reduce down to 4 percent.

As a matter of fact, you'll see in the next slide, and I'll talk about it in just a second, I just have a lot of dots right now. But we get down below one in that time period.

Regarding the flame acceleration, DDT that situation, you know we apply methods. I'd have to go back and review to what extent I described that in the FSAR. We followed a methodology as it states here appearing in the state of the art report on containment thermal hydraulics. Maybe you're familiar with it.

CHAIR POWERS: I'm going to have to truthfully admit to being absolutely confounded by the idea of DDT.

DR. MARTIN: What's that?

CHAIR POWERS: I do not understand DDT. I don't understand the experiments. I don't understand what's going on physically. And I certainly don't understand the methodology.

DR. MARTIN: Right. Well, and we were focus on flame acceleration, the criteria to basically show no flame acceleration. Without flame acceleration, we don't get DDT. So we tried to stay on that side of the fence that we didn't have to focus so much on those analyses.

So if I have not done a good job in there describing the methodology, it is certainly in the work we've done. It's been 2½ years almost, so --

CHAIR POWERS: You know the problem.

DR. MARTIN: I'm pretty sure after 300 some RAIs we've had, we've probably had something on hydrogen. But it hasn't been as big an issue as some of the other ones that we have focused on.

And here's one of the plots that appears in the FSAR on hydrogen. It identifies peak hydrogen concentrations during significant events. And the two I'll just focus on, under the two decided the peak hydrogen concentration in these analyses period. And you can see in the limiting case, we get about 8½ percent hydrogen concentration. And then you can look the one corresponding to the initiation of sprays which follows the 12 hours. And we didn't consider that as an uncertainty parameter. Twelve hours after the declaration of a severe accident we turned on the sprays in these analysis. You can see it's all under one percent here. Here's the little light blue dashes. And the other ones are at different phases in the event. You can see gate failure, two hours before that is so called near-RV failure. So there are other ones that are in between. These kind of bookend the events that are appearing in this slide.

CHAIR POWERS: So you activated sprays only after a period of 12 hours?

DR. MARTIN: Correct.

CHAIR POWERS: And you've got peak concentrations akin to hose at TMI. Kind of interesting. A universal constant 8.5 percent for large PWRs. And it's also worth noting that the pressure rise at TMI was only 26 psi.

DR. MARTIN: Right. Right.

CHAIR POWERS: So presumably it would be the same here.

DR. MARTIN: Right. And in our analyses regarding to combustion loads, our first pass at this we focused on 80 adiabatic complete combustion metric to evaluate those kind of limits. And maybe one of the open items that we have that Ed will talk about relates to the consequences of draft Reg Guide 1.203. And where in December of 2008 a new expectation was provided with regard to severe accident and combustible gas loads. And we've addressed those in, actually, we've basically sharpened the pencil because it has been needed to to address the changes to -- the coming changes to the consequences --

CHAIR POWERS: Why don't I suggest that

before we launch into MCCI, we take a 15 minute break.

DR. MARTIN: Fine. I ad so much momentum.

CHAIR POWERS: That's okay. We will do so, and then come back.

(Whereupon, at 2:27 p.m. off the record until 2:44.)

CHAIR POWERS: Let's come back into session.

DR. MARTIN: Okay. All right. The previous slide was on combustible gas control. In the FSAR to kind of highlight those five main areas with regard to stress and prevention. This next one relates to the core melt stabilization system. And that really encompasses from the time the corium comes into the reactor cavity until its final stabilized state in the spreading area. So there's several analyses that were addressed with regard to the CMSS evaluation. These are identified in the first bullet, the first one being examine the temporary melt retention and conditioning in the reactor activity. The next one as relates to gate failures and question whether the gate design was appropriate, whether in fact it could in some way impede the designed progression. It turns out to be a no never mind, but nonetheless, we looked at that.

MEMBER ARMIJO: Before you leave that what is the difference between the melt gate and the melt plug?

DR. MARTIN: Good question. Often times get confused.

The plug is that part of the concrete, the sacrificial concrete. It is the same material as the other sacrificial concrete that resides in the pit.

It is separate. I should say it's a moveable piece and it resides on top of this melt gate.

MEMBER ARMIJO: That's the aluminum thing?

DR. MARTIN: An aluminum thing.

MEMBER ARMIJO: Okay.

DR. MARTIN: That the plug actually rests upon as a -- well, it's a steel frame and the rest is aluminum, aluminum cover. It is designed so that during an outage or inspection or something, it could be removed. There is a mechanism, a cart say, that provides a means for removing that.

MEMBER SHACK: I have pictures of a guy lifting that plug up. And it just sort --

MS. SLOAN: Atlas.

DR. MARTIN: They're pretty strong guys. They're in Finland right now. We have a program.

The next study I'll briefly touch on is using the MELTSPREAD code, examining the melt-spreading process. Like I said, I'm not going to, of course, do it complete justice in the forum. Obviously, there's many really good plots and graphs and explanations that goes into some of the dynamics of it all. I'm just summarizing the results here.

And then the last one is the passive flooding and the long term heat removal of the spread melt.

Regarding the first one, the temporary melt retention and conditioning analysis. This was done exclusively with MAAP. Again, this is a version of MAAP, the incorporated models that are there to address EPR specific type issues and phenomena.

One of the goals was to demonstrate that the MCCI in the reactor cavity is still ongoing at the time in the lower head plus lower support plate have failed. That is the melt plug is still intact. This was a conclusion of our analyses. You can see later, and it's analyses that they got a different result with MELCOR, which is one of our open items that we'll talk about.

And along that lines, all of the incorporated material has been diluted in the MCCI pool,meaning that we have a well conditioned melt for spreading purposes.

MEMBER ARMIJO: But it's not going to be homogeneous? When you say "conditioned," what do you mean?

DR. MARTIN: Well homogeneous, I would say on some level, the mixing and the homogeneity of the metal and the oxide improves over time. Now again, we're adding light oxides to heavy elements of both oxides and metals. And so just the addition of the light oxides as well as the chemical reactions that are going on encourage this mixing process. This is something that has been demonstrated in test programs and it's observed empirically. So, yes, fairly well homogeneous.

The next analysis was done with WALTER. Again, there was some question early on whether the aluminum gate would in someway impede the progression and maybe even hold up melt in the reactor cavity. So we went off and showed that regardless of the melt composition, you know whether it's metal coming in contact which of course metal being highly conductive, thermal conduction, plows right on through the aluminum. And similarly the oxide it's a little bit slower, but even seven minutes the scale of a severe accident really isn't very long. And none of is considered the mechanical load that would otherwise be contributing to the failure. So this, at least in my mind, turned out to be a no nevermind.

The next one was the melt spread analysis. It was a very interesting analysis in which we look at, of course, the assumptions of what goes into the core itself, you know, prior to any kind of accident. So we considered it a constituents of fuel of the structure. And then, of course, we incorporate the constituents of the sacrificial concrete into a mixture. This is code input. It has the models that evaluate the viscosity of this composition and then evaluated the flow process and the multi-dimensional. Well, we a two dimensional analysis. And then it examines standing weights and the subsequent dampening of sanding weight. And so those are the kind of results that occur in the EPR.

And then this last one, long term heat removal analysis. A couple of goals here.

One, we had the question earlier about the load, thermal loads on the cast iron cooling structure. I mentioned at that time that we had identified a heat flux limit through these tests that we ran in our Erlangen offices. It turns out nine kilowatts, kind of our magic number that we're shooting for. And there is some margin of that, but nonetheless that one like staying below nine, we are below any concerned with critical heat flux in those cooling channels. Although we also showed in some of those analyses that even above nine we don't really have a problem with a little bit of boiling.

So that was one element of that analyses. And then the other side of it was, well, just look at how long it takes to finally stabilize and finally solidify and look at the temperature profiles out to 30 days, which I believe the next slide looks at both the near term and the long term.

There is separate with the metal and oxide. We assumed -- we took kind of limiting or bounding conditions with regard to thermal loadings and corresponding oxide levels, say, 90 percent oxide and just whatever happened corresponding to the limiting cases from our MAAP analyses. So that we would maximize the thermal load onto the spreading area floor, onto the cooling structure itself. And, of course, we incorporated the expected constituents which led to a lighter oxide on top of the metal.

In the left hand side plot we're looking at the thermal transient over six hours. So you can see the oxide, of course, is extremely hot. It doesn't take too long for the little bit of metal that's in there to get below about 2,000 degrees Fahrenheit and quickly establish a crust. Actually, MAAP will predict crust.

MEMBER ARMIJO: I can't read the dimensions on those charts. Are we looking at inches or what on these?

DR. MARTIN: Inches, correct. Yes. We used English units in our section, which has probably caused some frustration because we have gone back and forth with units with the staff on other RIA responses. But so much of the work came from Europe we tend to work in metric where we can. But to be consistent with the other chapters in the FSAR, we stuck with English.

So these are inches. And you can see we're about the thickness here -- well, it's like 13, 14 inches of melt within the spread compartment, which I believe is about 1800 square feet. I forgot to mention that earlier, but I believe that's right.

MEMBER SHACK: 1872 is what the topical says.

DR. MARTIN: Oh, okay. Thank you.

CHAIR POWERS: If you have melt spread

over this area and its hot, you -- enormous flux of radionuclides into the containment?

DR. MARTIN: It's a high surface area, and certainly you'd expect radionuclide transport to be dependent on the surface area of that. Now, of course, there's a relatively narrow chimney that it would be funneling through.

You have just a matter of seconds, really, before water comes in there. Now, as you can imagine, it doesn't immediately cover the surface of the --

CHAIR POWERS: It would be steaming.

DR. MARTIN: Yes, it would be steaming for some period of time. I believe in some rough calculations, about ten minutes I think we get a significant crusting of the surface and then you can start putting in some surface a bit.

CHAIR POWERS: You have some confidence that your flooding won't produce --

DR. MARTIN: Excessive?

CHAIR POWERS: Well, first of all, flooding if you bring it in, it's going to produce a lot of steam.

DR. MARTIN: Yes.

CHAIR POWERS: And then it's going to blow radionuclides out. The next question is, too, why isn't there a fairly strong fuel-coolant interaction?

DR. MARTIN: Well, because at a 100 kilograms a second you're not -- well, one, fuel-coolant interactions is also somewhat a function of more driven by the fuel. It's the breakup of the fuel and kind of the self-perpetuating nature of the breakup that leads to the rapid energy transfer to the water. But all the water converts to steam in that early phase. You get a 100 kilograms of water into the spreading room and a 100 kilograms of steam early on until you can wet that surface. But we also --

CHAIR POWERS: You know, it seems to me that experiments we've done in which the core melts, poured water onto melts and they got detonations. The core in alternate contact mode, steam explosions.

DR. MARTIN: Yes.

CHAIR POWERS: And my recollection of the way -- which is reasonably accurate since I use it in the class I teach, is that they bolt the concrete pad underneath the crucible where they've had the --

DR. MARTIN: Yes. Well, you know, I'd have to obviously confirm my statements. But I believe the reason for the flow limiter is to keep this below any sort of threshold to cause an alternate contact fuel-coolant interaction type situation.

CHAIR POWERS: And usually the problem that you have on the -- on the surface, is you're also not boiling the water very fast so that you have liquid water there. And if you have any instability in the molten material surface --

DR. MARTIN: Yes.

CHAIR POWERS: -- then you get into this divine netherland of what causes steam explosions.

DR. MARTIN: Right.

CHAIR POWERS: And I'd have to admit to a certain amount of ignorance there.

DR. MARTIN: And, obviously, we have a high degree of uncertainty. You know, we do have tests. The silica content in the sacrificial concrete also improves the surface for wetability. And also it improves the melt with regard to fuel-coolant interaction. It also improves the radionuclide transport in cases. So there's a lot of advantages, of course, to having that first phase in which the melt gets conditioned and the silica is a big part of that.

So moving on to the long term, that is the right hand side. We did this with the WALTER code looking at six hours to 30 days we can see that under the assumptions of now active flooding in which the

SAHRs, the severe accident heat removal pumps, are in operation and underneath the cooling channel, basically a steady state heat removal within a couple of days you can see the blue line just peaks over the solidus temperature that is identified by the dotted line in that figure. But within a couple of day or so we've effectively solidified the melt within the spreading area and long term plans, of course, can then be made about eventual recovery and decommissioning.

High pressure melt ejection. And I'll somewhat combine the discussion in the FSAR on high pressure melt ejection and in the next slide on fuel-coolant interactions. Also cross referenced is the work that was done by our PRA team, Dave Gerlits, primarily. There they did their own phenomenological evaluations and then we supported them.

I believe I mentioned earlier the analysis that we did with calculating the RCS pressure at the time of failure. I mentioned about the ten or 12 bars.

So we complicated their --

MEMBER SHACK: That was the one system, right?

DR. MARTIN: That was just one train, correct. So I was a little conservative going in.

You know, you don't have a lot of freedom to redo this things and sharpen the pencil in all these cases. But it was acceptable to go forward with those kind of results and discuss about the remoteness of high pressure melt ejection, even in this more extreme case with the assumptions with PDS activation and the use of one train.

Nonetheless, the high pressure melt ejection is really handled primarily in 19.1 complimented by the qualitative discussion and the use of the uncertainty analysis to demonstrate the kind of results we were getting with MAAP. So it's really a two-fold response to addressing high pressure melt rejection.

CHAIR POWERS: The response addresses the dispersal issue and the potential for getting literally direct containment heating in the atmosphere. I'm still left with this anxiety over the recoil of the vessel, whether you get that or not and the behavior of the penetrations through the containment. Do you have anything on that?

DR. MARTIN: Well, again, I think in the Level 1 analysis I can't recall to what extent Dave Gerlits had talked about that, but I know it came up. I would have to yield to the work done as part of the

PRA and following their needs with regards to addressing all these issues, and that being among many. But I believe it's all included in the phenomonological evaluation. But it is addressed in 19.1 section.

But you can see here, my second bullet, you know Dave and his team were following the precedent established in the staff's NUREG/CR-6338 and then some of the work done overseas. And I can't pronounce FZK, but in their document in Germany.

CHAIR POWERS: I think that doesn't exist anymore anyway, so --

DR. MARTIN: Did they change their name?

CHAIR POWERS: Oh, you betcha. Twice.

DR. MARTIN: Okay. In a similar vein, the discussion on FCI, it focuses qualitatively on the design features or the characteristics of the EP that minimize the potential contact for fuel-coolant interaction and also -- actually, I believe I incorporate by reference the discussion in the topical report where I make reference to FARO and other tests that effectively in the minds of those researchers resolved fuel-coolant interaction issue for other plant designs. And again --

CHAIR POWERS: Well, it may have resolved it in their mind but somehow Koreans and other people seem to persist in doing experiments in the area.

DR. MARTIN: The more experiments doesn't hurt, does it?

CHAIR POWERS: Well, you won't like these experiments. They get explosions whereas FARO seemed to be star-crossed as far as their ability to get explosions.

DR. MARTIN: And likewise, the Chapter 19.1 phenomenological evaluations examine this using methods which precedent has already been established. Again, I'd have to defer to the PRA team on specifics of that. And again, I believe it was discussed at the February 18-19 meeting.

CHAIR POWERS: Your last bullet speaks of containment failures. And you'll have to forgive me, where do I look for your analysis of fragility of your containment?

DR. MARTIN: Again, as in 19.1?

CHAIR POWERS: It's in 19.1.

DR. MARTIN: Yes. And of course, that's much bigger than 19.2, so --

CHAIR POWERS: And this was an ABAQUES-type calculation?

DR. MARTIN: Can you speak to that Nissia.

MS. SLOAN: Introduce yourself and --

MS. SABRI: Nissia Sabri.

I joined AREVA two years ago. I have been working since then with the PRA group on the U.S. EPR, mainly on Level 2.

My degrees are in nuclear engineering, graduate degrees from engineering schools in France and University of Florida.

CHAIR POWERS: Which schools in France?

MS. SABRI: INPD, it's in Grenoble.

I'm afraid I didn't actually hear the whole question.

CHAIR POWERS: What I did was confess to not doing all my homework. And I have not looked at the containment fragility analysis.

MS. SABRI: Okay.

CHAIR POWERS: And I asked where it was, and then I was told, fairly I had not my homework and I knew I hadn't. And that I asked if that fragility analysis was done with something like ABAQUS?

MS. SABRI: Well, to answer your first question, the containment fragility is addressed in the FSAR. There is specific section where we have the fragility curve that we have generated using Monte-Carlo methods based on deterministic inputs from the structural group that was done using ANSYS.

I will not be able to give you all the details, but the thermalistic structure analysis I believe it will be covered when that chapter will have the ACRS meeting. However, I can just give you on how the composite fragility curve derived. It was basically the containment was divided into six sublocations and we had as input, the median pressure of failure as well as the uncertainties that depend on the methodology and the material. They have been given to us and evaluated by the structural team. And then using that, we did a composite fragility, as I said earlier, using Monte-Carlo methods. And the composite reflected actually the weakness location in the containment, and that was the base of the dome in the containment.

CHAIR POWERS: The base of the dome?

MS. SABRI: Yes.

CHAIR POWERS: What we see fairly routinely in experiments with containment models is hat failures seem to occur always at details in the construction that are below the resolution of models. And it is common for equipment hatches and things like that to be those locations.

And the question is have you done a fine enough gridding to identify the most susceptible locations for failures and is there a sufficient margin between the pressures we anticipate and the failure pressures at those localized areas?

MS. SABRI: Well, we have actually a margin between the design basis pressure and ultimate pressure, factor of about 2.9 almost --

CHAIR POWERS: You saying 2.9?

MS. SABRI: Yes. And for the completeness of the study at this stage it focused on fragility concerning rupture of the containment. It did not cover equipment actually penetrations that are, for example, personnel hatch. A discovered hatch, however, a closed hatch basically. A discovered hatch, the hatch was one of the locations that was explicitly modeled. However, it's when the hatch was closed and there is --

CHAIR POWERS: That's fair. I don't object to that.

The other question is we routinely critique these is that they use core properties. Did you use core properties or did you have temperature dependent properties?

MS. SABRI: We did initially have different fragility curves depending on temperature, and that was on cold temperature transients as well as third type of accident. I believe it's in the process of a revision of the containment fragilities for any other temperature than just the design basis temperature.

CHAIR POWERS: Okay.

MS. SABRI: So the current fragility curve in FSAR is only represented for one temperature.

DR. MARTIN: Okay. Thanks, Nissia.

The next subject is equipment survivability. In this section we identify, of course, several systems, structures, components for which equipment survivability evaluation is necessary. We incorporated our uncertainty analysis to identify key figures of merit, pressure, temperature, humidity, radiation. We also looked at certain specific areas for survivability questions. For example, thermal loadings on the PDS valves. Let's see, I had another example in mind.

Oh, loadings in the reactor cavity for which we make a statement about a 20-bar limit and we have analysis accompanying that.

We can also add in, you know through the PRA process, we had several questions with regard to thee bar survivability. That certainly falls in the same vein.

This particular plot is one of a couple that take the results from the uncertainty analysis and look at different events and create a envelope, in this case pressure and temperature, that we might expect during a severe accident event. And these are kind of bounding results.

Now we will incorporate these results. We will certainly refine these results with best estimate type analyses as well and come up with a complete equipment survivability plan so that we can move into procurement element. This is a detail design task, but it's a considerable amount of effort that goes into the detail design effort to identify the specifications and components and particular instrumentation. Much of the severe accident response in the EPR is passive because of the ex-vessel approach. But one of the most important things becomes the monitoring element and the instrumentation. And so there's an emphasis there when it comes to survivability questions. And as a matter of fact, we're kind of working in that area right now back in Lynchburg.

Okay. This slide kind of follows up the three-fold strategy that I mentioned early on. Of course, I've talked about the estimate calcs and the uncertainty analyses extensively and then how they are reflected in the results and presented in the FSAR.

Complimenting those are, again, analyses that we did in the beginning to determine the fidelity of the model. I've talked about the WALTER and the METSPREAD analyses, some of those survivability calculations are incorporated here. But I wanted to incorporate this slide to kind of reflect and kind of close the loop on the methodology approach to the calculation metrics. This of course can be added on to or probably has been added on through RAI process, primarily. And even going beyond as we look at the next subject, accident management.

Again, we'll have a considerably more deterministic studies to compliment an uncertainty analysis base approach, a similar approach.

This slide, of course, moves away from the severe accident studies focused primarily on containment integrity. Moves into the severe accident management guideline development space. Obviously, the utility is expected to have all its emergency plans in place prior to getting an operation license. And we as AREVA provide a lot of the kind of leg work through a methodology we call Operating Strategies for

Severe Accidents. Of course, the whole point is that severe accident management extends to the defense-in-depth philosophy to plant operating staff by extending operating procedures beyond the plant design basis.

What I've provided staff so far, or at least initially through FSAR, is a summary of this approach where we describe some severe accident challenges, some candidate entrance/exit criteria, some preliminary response strategies, some end products.

Through the RAI process if we got a more detailed question, and we've provided an extensive response. So that we've gotten a follow-up question. Well again, that'll go more into it. And then we'll expect to have even more information along this line. But it's like emergency operating procedures. It's part of detailed engineering. And what we have today are methodologies. We've done some analyses. Certainly it's farther along at OL-3 in Finland, so we have insight from their experience and certainly we're drawing on that to the best of our ability. You know, there are some design differences and we have to address that as well.

So it's a work in progress today. We have methodology and an ongoing dialogue with the NRC staff with regard to what we term OSSA, Operating Strategies for Severe Accident.

Section 19.6 address severe accident mitigation design alternative or the analysis for SAMDA. It's an evaluation of plant design alternatives that could significantly reduce a radiological risk from core damage.

What was prepared for the FSAR applied existing precedent in SAMDA analyses incorporating the work by NEI and also NUREG/BR-0184 reports. We also expanded the analyses methodology in those reports to incorporate our own, U.S. EPR-specific hardware and actions and procedures.

In that original analysis we identified the maximum benefit of 51,000. We've gotten some feedback. And you see the last bullet, because I'm jumping a little bit, a rev to that last year. And I believe the maximum jumped up to like 71,000. But don't quote me exactly on that.

So nonetheless, the evaluation completed that additional plant modifications are not cost beneficial.

And if you like, we could talk about the-- maybe we'll save that.

CHAIR POWERS: Any other questions you'd

like to pose to the speaker?

MEMBER ARMIJO: Yes, I got a question. On your page 70, and I got to confess I'm not familiar with your system design. So the drawing shows the spreading compartment. Slide seven zero.

DR. MARTIN: Okay. All right.

MEMBER ARMIJO: Yes. And the same cooling line that cools that cooling plate also provides a flooding of the melt in this spreading compartment, is that correct?

DR. MARTIN: Let's see.

MEMBER ARMIJO: That line goes --

DR. MARTIN: You were looking here?

MEMBER ARMIJO: Yes.

DR. MARTIN: This is the passive line.

MEMBER ARMIJO: Right.

DR. MARTIN: And maybe, Mike, you can help me with this a little bit. Because you've got the most experience I think with the FSAR.

MR. BINGHAM: Yes. When the thermal actuator opens the valve in the spreading room, it opens one of these little valves to the right there.

MEMBER ARMIJO: Right.

MR. BINGHAM: Yes. So the water flows through the passive outflow reducer, that circle there, and flows passively along the orange path through the clean channels and then up on top of the melt.

MEMBER ARMIJO: Right.

MR. BINGHAM: That's just the passive portion. So then during the active --

MEMBER ARMIJO: Now that same cooling line cools the plate, this cooling plate?

MR. BINGHAM: The cooling channels?

MEMBER ARMIJO: Yes.

MR. BINGHAM: Yes. That's right.

MEMBER ARMIJO: Now if in the event if you had a blockage of that line for whatever reason, do you have another way of flooding the melt in the spreading compartment? Is there another way that you get water in there?

MR. BINGHAM: There are two lines. This only shows one, but there are two lines.

MEMBER ARMIJO: There's two lines?

MR. BINGHAM: That's right.

DR. MARTIN: Fifty kilograms is right, isn't it?

MR. BINGHAM: Right. I think so.

DR. MARTIN: More or less.

MEMBER ARMIJO: But they're just --

MR. BINGHAM: Passive.

MEMBER ARMIJO: -- passive. So it's just the head water is moving back and forth?

MR. BINGHAM: That's right. That's right.

CHAIR POWERS: Any other questions?

Well, thanks very much.

MS. SLOAN: Mr. Chairman, before we go, Hanh was nice enough to share with me one of your questions was what components of the SAHRS are in the RAP list and Hanh has had the RAI number, it's RAI 268 question 17.4-22.

CHAIR POWERS: So there. Now you know.

MR. TESFAYE: Good afternoon. Let me just get started here.

Prosanta Chowdhury is the Chapter PM. Since he has to leave early, I'm taking over as Chapter PM.

This portion is the staff's presentation of SER open items. You're familiar with Ed Fuller who got his Ph.D. in the last century, the middle of last century.

MR. FULLER: A few years before Dana got his.

CHAIR POWERS: The day before yesterday we had a speaker introduce himself by saying that he'd worked in six different decades.

MR. FULLER: That's all?

MR. TESFAYE: And I think with that, I'll let Ed get started with page 77. That's where we stopped back in February. And then Jim Xu will have a portion of this presentation also.Ed Fuller who got his Ph.D. in the last century, the middle of last century.

MR. FULLER: Okay. I am not going to go through our entire review. I'm just going to focus on open items. That's not to say that if you have any questions of us about items that we don't discuss, we wouldn't be prepared to answer them.

CHAIR POWERS: Yes. I think it's fair to say that we're going to be back on this stuff.

MR. FULLER: Yes. We're jumping right to severe accident mitigation features. We won't be discussing the prevention features because we had no open items there.

Besides, you know, Bob really gave an excellent presentation to give a really perspective on the breadth of their application for Chapter 19 Section 2. So it's okay for me to skip, I think.

Let's start off with hydrogen generation and control systems related to severe accident mitigation.

We reviewed the combustible gas control system and the hydrogen monitoring system descriptions and various analyses. Asked quite a few RAI questions and got some extremely detailed responses. I think I told you last time that we designed some of our questions to get as much information on the docket as possible. And a couple of RAI responses related to the hydrogen control to hundreds of pages because they gave us all kinds of graphs that came out of MAAP calculations. I was impressed, but obviously didn't look at them all. But we did look at key things.

And we thought, at least in terms of the overall conclusions, that their analyses were reasonable. Of course, we did ask for additional information pertaining not only to the PARs, but also to the way the gases would mix in this normally "two-region containment," which opens up to a one-region containment when these dampers open and so on and so forth.

So we asked some questions related to potential for flame acceleration to DDT conditions. And we got some responses that we thought were reasonable.

In particular, Question 19-235 the

response to that did show large margins to potential flame acceleration or detonation in the various regions as they were modeled by AREVA.

We did perform some confirmatory calculations, and actually we're still doing this. We did calculations for the representative accident scenarios, not just the "relevant ones" that Bob talked about, but representative of certain scenarios that may not have necessarily been the big ticket CDF items.

And we did confirm that as far as, at least when their model was working as designed, efficiently recombined the hydrogen and the oxygen as we determined that as long as this system works as designed, there would be little potential for forming pockets of high hydrogen concentrations. And therefore, we wouldn't expect a large deflagration during any of those scenarios.

We are, though, looking at conditions where the efficiency of the FSARs is reduced, sort of step-wise downward, to see what the impacts would be. And we're doing this work with our contractor ERI and working in conjunction with the Containment Branch. So that we're going to make sure that we get comprehensive set of responses that satisfies our needs for both Chapter 6 and 19 out of this.

Okay. Let's go to the next slide.

We probably spend more time on systems related debris coolability than to any other ones in all of our reviews of design certifications for severe accident evaluation. This one's no exception. So we've asked a lot of questions. We still have some open items here which I'll get into in a second.

CHAIR POWERS: Let me ask you question.

MR. FULLER: The next four or five --

CHAIR POWERS: Let me ask you question.

MR. FULLER: Yes.

CHAIR POWERS: Did you do an analysis in which you just assumed that all of this stuff doesn't work? The melt comes down, close out, there's no water at all and look at the containment pressure there versus the containment pressure when it does work?

MR. FULLER: Yes. We actually asked AREVA to provide us with that kind of an analysis. And they did provide it.

CHAIR POWERS: And did they get into trouble with that kind --

MR. FULLER: Well, the short answer is yes. If for some reason the melt plug/gate never works and the debris gets trapped in the cavity, then you get significant basemat penetration within 24 hours.

If the severe accident heat removal system doesn't work and you get core debris into the spreading room and no water comes in, likewise the calculation is that you will have a significant core debris concrete interaction leading to significant oblation.

So, yes, we did do those. In those I'm not sure if -- yes, we got down to the plate. Definitely got down to the plate.

CHAIR POWERS: Yes. But you didn't overpressurize containment?

MR. FULLER: Well, eventually you did, yes. I don't remember the details.

CHAIR POWERS: No.

MR. FULLER: And hold on, I think I want to ask Mohsen Khatib-Rahbar to talk about what our melt core calculations might have shown here too.

MR. KHATIB-RAHBAR: We did the calculation where we assumed the cooling on the spreading area would not occur, and this would result in MCCI. We do, of course, get significant penetration of the concrete but it does not pressurize the containment as failure condition. The pressure still remains low in the containment.

MEMBER SHACK: Is that with the spray working or that's without the spray?

MR. KHATIB-RAHBAR: Without spray. Dry, totally dry.

MEMBER SHACK: Totally dry?

MR. FULLER: Okay. The next three slides I'm going to skip because Bob did a much better job than I could do explaining how the core melt stabilization system work, as well as the severe accident heat removal system. So unless you want to revisit any aspect of that, we'll just skip those and go to Slide 81.

I want to focus on one of our open items here. And we're in the cavity or the pit here. Just after vessel breach the debris would have to, as you know, penetrate the sacrificial material and then fail the melt plug and go through the gate. And AREVA's calculations using MAAP indicated that by the time this happens you've gotten essentially all of the core debris out of the vessel. And it's mixed itself quite nicely with concrete, core concrete interaction reaction products and then flows down the channel into the spreading room.

We find that, you know we had some questions about the refractory material behind the sacrificial material both in the walls and on the floor. And noting that these bricks have a low thermal conductivity and mechanical strength greater then concrete, but we're not sure about what happens when its attacked because it's brittle and subject to failure by thermal shock. So we asked the applicant to demonstrate that its integrity could be maintained during severe accident conditions. And we were referred and they provided us with some priority reports that we looked at. And by in large, we're getting pretty comfortable with their argument but there are some questions that still remain. And because of that, this RAI 19-332 remains an open item.

I would guess that we have to really talk about these in detail, we would have to arrange a closed meeting.

MEMBER ARMIJO: My question would be on the bricks. Are they bonded to the concrete as those failure of those bonds could result in the bricks, basically? Not providing any protection.

MR. FULLER: I don't know the answer. Is that a priority set of piece of information?

DR. MARTIN: I'll just comment. Again,

this is Bob Martin.

It's part of your question, I believe, 19-332. And we're addressing that --

MEMBER ARMIJO: There is an RAI on that?

DR. MARTIN: Yes. This is referred to as 19-332. This was issued after the SE draft was given to us. We got a handful -- actually we continue to get a few questions here. This 332 said 349 was received by the late January time frame, I believe.

MR. FULLER: Yes.

DR. MARTIN: And we've started the work activity to address that. And that element of your question is --

MEMBER ARMIJO: Well, you know the other part of my question is there's all kinds of formulations of zirconia: The density, there can be additives to stabilize the zirconia, yttrium for example. So I just wondered does the staff have that level of detail information?

MR. FULLER: Well, I think in the response to question 312 we might because that was a very detailed response. And again, there's a lot of priority information in there, which I'm sure you folks could get privately.

MEMBER ARMIJO: I'd like to get that.

CHAIR POWERS: I mean, it's kind of surprising not to use stabilizer zirconium, because it's not that much more expensive than unstabilized.

MEMBER ARMIJO: It may be, he just says zirconium, and I don't know if it --

CHAIR POWERS: Yes. Stabilized zirconium is dirt cheap.

MEMBER ARMIJO: Yes.

CHAIR POWERS: I mean, none of them are dirt cheap, but they're not that much different.

MR. FULLER: They're testing programs too. I'm sorry in respond.

CHAIR POWERS: The interesting question that comes up is how you choose the sacrificial material. Because if it's the highest silica materials, that creates a acidic melt which corrodes zirconia pretty badly. And if you choose a more calcium-rich material, that's a basic melt and it goes after zirconia very quickly.

So choosing the right sacrificial material is kind of an interesting problem.

MR. TESFAYE: I will take an action to provide you these RAI responses.

MEMBER ARMIJO: Yes. Thank you.

MR. FULLER: Okay. Let's go to slide 82.

Continuing on, another question that we had regarding behavior in the pit is because, as I said before MAAP calculations indicated that all of the core debris was out of the vessel by the time the plug failed, whereas in our confirmatory MELCOR calculations that wasn't the case. And that there may be quite a bit left when it fails. And this has some implications on possible energetic molten fuel-coolant interactions. Because if you think about it, if the core melt goes into the spreading room and whatever the inventory was at that point, and then water comes in on top, floods back up the channel and perhaps into the cavity, if at that point a substantial portion of the core debris that was still in the vessel comes out, you're opening yourself to the possibility of an ex-vessel steam explosion.

And so we've asked them to evaluate this. And this follow-up RAI 349 question, 19-332 it's one that they're still evaluating as well. So this is an open item at this juncture.

CHAIR POWERS: Did you look at the delta contact mode explosion potential?

MR. FULLER: We didn't look at them, per se. We were asking them to evaluate the potential.

CHAIR POWERS: Yes. It just seems to me

that they have a potential of alternate contact mode. Now the consequences of that I'm uncertain of. I mean, it's in the lower cavity, who cares. You can blow things up like crazy and it just doesn't make any difference because there's nothing to damage there. But this is interesting that we don't seem to have -- you know, we have elaborate detail in some aspects and then here's this explosive potential demonstrated by experiment that putting water on top of melts they will explode even when the water won't wet the meld because you're above the Liedenfrost temperature. And that gets no never mind and it's kind of curious.

MR. FULLER: Right. So this is something we need to get a better handle on before we can close this particular item.

Okay.

CHAIR POWERS: The reason to pay attention to ex-vessel steam explosions as far as I see it is it's a way to mechanically commutate the melt and you get otherwise relatively nonvolatile fission products launched into the atmosphere and available to leak from the containment, even if the containment has not grossly failed. And that changes the mix of fission products you're dealing on the great out of doors and a different consequence analysis then you might otherwise expect.

MR. FULLER: Slide 83. Continuing on in debris coolability space, there is a set of questions that are basically trying to get at what some of the differences are between the MAAP calculations that AREVA did for this application and our MELCOR confirmatory assessment calculations. I don't list the details here, but if you look at these questions you can get a feeling for what they might be. I also list in the SER with open items.

There's some questions that I list here that are related directly to debris coolability. And there were one or two other questions related to the hydrogen control as well in that set.

Assuming that we resolve these, we believe that if the core melt stabilization system works as they designed it, they'd probably with pretty good reliably be able to arrest the core concrete attack. And in conjunction with a severe accident heat removal system design they could avoid basemat melt-through and keep the pressure from failing in the containment, and temperature relatively cool as well.

CHAIR POWERS: Have you looked at what happens in an earthquake-induced accident for this system?

MR. FULLER: No. I think you've made an interesting point before when you talk about how an earthquake can probably degrade certain structures in some way which might alter the course of an accident progression. But I haven't the foggiest idea how that would work out.

CHAIR POWERS: Yes. I mean, I don't know. Certainly can't do the integration in my head, so --

MR. FULLER: No, we haven't looked at that. The way we look at earthquake-initiating events, they are basically contributors to losses of systems and loss of off-site power is obviously high up on the list.

Back in one of my former jobs when I was a consultant doing a project for EPRI, we looked at steam generator tube integrity risk assessment. And we did a project on the Diablo Canyon plant. Obviously, that one is probably the most studied plant in the country with respect to seismic events.

It turned out that the major contributor to risk was from earthquake-induced station blackout type of events leading to a possible induced steam generator tube ruptures is the tubes are damaged. Now it wasn't even close. It was more than twice the internal events of power. Of course, that's the extreme.

But I think if you look at various plants carefully you would find that seismic initiators are quite important.

Okay. Let's go to the next one.

We talked about high pressure melt ejection a little while ago. And, of course, the EPR design has the primary depressurization system which with a very high reliability, would lower the RCS pressure if you stared off an accident with transient in high pressure. And not only that, we discussed the cavity with its tight confined vessel above it and the tortuous paths, which happen to lead, actually, to steam generator compartments and pump rooms, and the like.

When I looked at some of their MAAP analyses, I saw that after depressurization their RCS pressure wasn't all the way down. It was in the order of a little less than 200 psi. And that would mean given the tortuous paths is very little core debris would make it into the upper containment. However, there would be significant relocation into these other compartments. And this is consistent with the set of experiments that were done at Karlsruhe. And I think I brought these up last time.

And what concern is that we believe that in developing their accident management technical basis, which would turn into SAMG eventually, that they need to take the presence of core degree in these rooms into account and whatever that core debris might do to fail certain monitoring systems or other things that are usually expected to be there during the severe accident.

We realize that AREVA's really taking a close look at this kind of thing from the equipment survivability point of view, and they do talk about this in their OSSA documentation. But this is one of these follow-up accident management items that we just recently asked them to consider.

Next.

Containment bypass. Well, there are two classical ways to look at it in these PWRs. One is from steam generator tube ruptures. The other one is from interfacing system LOCAs. And they've gone out of their way to beef up the piping systems so that they can withstand as much pressure as the primary pipes can.

So looking it over we don't believe we need to worry too much about severe accident consequences from an ISLOCA. The probabilities seem to be very, very low. However, the possibility of induced steam generator tube rupture in high pressure scenarios is still something that we're concerned about. And we believe that it is important to have the depressurization valves open in a timely fashion.

We asked them a question, question 19-240 in RAI 133 asking them questions about this. And they gave in their answer some information that indicated that the time between when the core exit temperature reaching 1200 Fahrenheit and when induced steam generator tube rupture might occur if you hadn't depressurized after that, might be expected to be between 18 to 20 minutes assuming a hot leg nozzle wouldn't fail it first. And that was a function of the degree of core tube damage.

We also asked them to do this for scenarios where the secondary side was depressurized, because that's when you get in trouble.

So that gives us a good feeling for what we're looking at. But we believe that they need to make sure that this kind of information is factored into their OSSA, their severe accident management technical basis. And so another question we've asked in that latest set is to give us more information on this on how they're going to address it in OSSa and how their Human Reliability Assessment would be utilized in this regard.

Okay. Now we have a little break because Jim is going to be discussing the containment performance.

MR. XU: You want me to introduce myself?

MR. TESFAYE: Yes, go ahead and introduce yourself.

MR. XU: My name is Jim Xu. Senior Structural Engineer from Structural Engineering Branch, NRO.

I have been with NRO for three years and I've been primarily responsible for review of COLAs related to structures, circulating structures, the components.

And prior to joining NRC, I worked at Bookhavan National Lab for 20 years. I primarily worked on the NRC and the DOE projects to address seismic and nuclear safety issues.

And then I have a Ph.D. in structural engineering. I think I should be qualified to answer all your questions that you have.

CHAIR POWERS: Okay. How does the cross nodalization system behave in an earthquake?

MR. XU: I could answer that question --

but then I'll answer whatever question you may have.

Okay. On the containment performance capability, what we're focused here is on the structural aspects. And the staff's review focused on two issues.

The first issue has to do with Regulation 50.44, you know that series is related for pressure build up in the containment due to 100 percent fuel-coolant interaction for the hydrogen burning, what is the structural class. And according to 50.44(c)(5) and Reg Guide 1.7 the applicant needed to perform analyses assuming 100 percent fuel-coolant interaction and develop the pressure and the temperature time is free from containment and to perform a structural analyses of containment that determine that the demand on the containment and compare that with the ASME Service Level C limit to ensure that whatever demand due to the water-metal reaction will be below the ASME Service Level C stress and strength limit.

MEMBER SHACK: How does that Level C limit compare with the ultimate limit that I get from a fragility analyses?

MR. XU: There are two different attributes. The Service Level C elements are a very conservative limit because these are design limit.

MEMBER SHACK: But it's like twice the design limit, right? Something like that, roughly?

MR. XU: Yes, it's --

MEMBER SHACK: That's the number I keep in my head.

MR. XU: It may be even bigger. It may be even bigger, yes. Because, for example, for the liner strength the ASME Service Level C limit is .3 percent. And if you go over the fragility and test that, it will show the liner can stretch to, you know, 2 percent or higher. So the Service Level C limit is a very conservative capacity.

So we have open area on this issue. And we didn't receive AREVA's response to our RAIs, but that was received after we prepared an SER on these slides. So, as a matter of fact, next week we're going down to AREVA's site to perform all the analyses related to this RAI. So we'll probably examine more in details.

And basically on their RAI response, and the response basically formulated to answer our RAI questions and it basically said that they analyses. They have, you know, checked with ASME Service Level C limit, and they demonstrated that the demand is below the limits. But we have to verify that. And to see if the containment analysis did perform adequately. That will be done next week. That's my first slide.

On my second slide this one deal with the containment deterministic performance goal, which is the staff goal approved by the Commission through SRM through SECY-93-087.

This goal is very similar to the previous slides, except the loading is different. Because the previous slide deal with the hydrogen load, which probably has a lower frequency then what would be in here.

And according to SECY-93-087 there are three aspects -- or two aspects they need to address. For the more likely internal challenges, I mean this is a very fuzzy kind of term. And we do have Reg Guide which the pre-decisional form has been development, I think end of the last year. I don't know the status of that right now. It's Reg. Guide 1.216. So I don't know the status, if it has officially been issued yet. But that guide provide, you know detail guidance how --

MR. FULLER: We're going to be looking at that shortly.

MR. XU: That will be good, yes.

And for more likely internal challenges, I mean when we review the -- and we found out that they had not drafted this issue. So we had to issue an RAI and this is the same situation, actually in the same set of RAI response, they responded after we prepared an SER. So it's not reflected in here.

But the issue has three parts. One is the group of the more likely accident events. And the applicant regarding the second accident need to demonstrate for the pressure temperature generated from those events but containment structures will be below -- that the event will be below Service Level C limits. Okay. For initial 24 hours after the core melt. And then the applicant need to demonstrate after 24 hours the containment would continue to provide a barrier against uncontrolled release of fission product.

And, you know I looked at the response and they did have addressed all the issues, you know we asked for. And they have demonstrated that the demands due to the internal challenges are formed below the Service Level C limit and that they also show the up to 24 hours the pressure and the temperature do not increase again. So it's basically from decay half of melt.

So, but again, we will review in detail next week their containment analysis and to see if they have found that was always in details. So want to see the containment analyses.

So these are the structural issues we have asked for the containment structural performance.

And if you have any question on the seismic, you know, I'd be glad to answer it.

CHAIR POWERS: Okay.

MR. XU: In fact, I also want question because it continue to come up on whether the severe accident analyses has considered the seismic as an initiating events. And the answer is that the severe accident space and the seismic space do not intersect. But that mean as their feeling was extremely low probably events.

Even if you include that low sequences in the seismic PRA, the old seismic core damage purpose it will not change much. The seismic core damage frequency are critical in the range of ten to the minus 4 and ten to the minus six. Okay. What didn't here is lower than ten to the minus eight core damage sequences. So, you know, whether you include them or not, it will not impact seismic.

CHAIR POWERS: I guess I just don't understand the argument there. It seems to me we have a low internal event frequencies at this plant.

MR. XU: Yes. Right.

CHAIR POWERS: Consequently, the seismic initiator, which is roughly ten to the minus six --

MR. XU: Yes.

CHAIR POWERS: Argue with me plus or minus a factor of ten and it didn't make any different. And so it becomes kind of frequency-dominant initiator here.

MR. XU: That's right. Yes.

CHAIR POWERS: And so you ask well what does that do with all of this accident phenomena that I've looked at? I mean, here I have a structure, it has a connection of fairly weak nature between that and the containment foundation. Those things seem to be ripe for the discontinuity of motions renouncing one of the dominant consequences of earthquake event. I mean, to me it's a fairly obvious question. What happens to this core stabilization system --

MEMBER SHACK: If you're going to mitigate a severe accident, why not pick the most likely severe accident --

CHAIR POWERS: That you're going to have.

MEMBER SHACK: -- that you're going to have.

MR. XU: The frequency is low. In the

seismic PRA you have a screening criteria. So it would not have any contribution -- the situation would not have any contribution on core --

MEMBER SHACK: Yes. But I think the argument is here, you know a mitigating system to mitigate internal event core damage, which has a frequency of ten to the minus seven and your guess is that seismic are going to be larger than that by some number, ten to the minus six.

MR. XU: I think the impact would be not on the core damage frequency side, it would be on the LRF. And for that, I mean I haven't seen any seismic for PRA perform for our --

MR. FULLER: Well right now all they're doing is seismic margins analysis.

MEMBER SHACK: Well, you know, Dana looks at the structure, I look at the SAHR system and wonder if it's seismic qualified. I mean, that would be my sort of question about it. I'm less worried about the structure, but the SAHR system certainly ought to hang together and work.

MR. XU: But the containment typically has a very high seismic -- typically has more than 1g HCLF.

MEMBER SHACK: That's the containment?

MR. XU: Yes.

MEMBER ARMIJO: What about the piping, you know the water line that goes into the spreading compartment, those kind of components.

MEMBER SHACK: The pump?

MEMBER ARMIJO: Yes.

MEMBER SHACK: The pipe, the valves?

MR. XU: Well, the only part I know that is not seismic for design is the containment spraying, but I don't know other components --

MEMBER SHACK: Well, they're non-safety.

MR. XU: They're non-safety. If they're non-safety, then they're not seismic qualified. So we cannot credit that in seismic events, which would assume them to fail during seismic.

MEMBER SHACK: Well then it does come back to it just seems strange to have a mitigating system that doesn't work on my most likely initiator of a severe accident.

MEMBER ARMIJO: Yes.

MR. XU: But at least they cannot credit the containment spray for seismic event.

MR. FULLER: Shall we go to the accident management now?

Yes, I was leading up to this with a

couple of slides before.

AREVA's has got this operating strategies for severe accidents project which actually looks really good to me. They're still in the stage of putting together all of the details of it. And I do know when they do get it together, they would like it to do is to provide mitigation strategies to cover all events leading to core melt, I guess including seismic, and to stop or reduce the release of fission products to the environment.

And they, of course, tie this just like the existing severe accident management strategies for existing plants, they tie it to the emergency operating procedures that would presumably prevent core damage.

And they've actually got a -- I wish they would put up this OSSA figure showing the transition between the operating --

CHAIR POWERS: I think they did at one time, didn't they?

MR. FULLER: It's got three regimes in it.

CHAIR POWERS: Yes.

MR. FULLER: It's in there OSSA documentation.

CHAIR POWERS: I think in one of their

presentations they showed that transition, the various regimes.

MR. FULLER: But it gives you a good feeling for what they're up to.

The way I see it, it boils down to being a passive approach for the first 12 hours relying on the combustible gas control system and the other hydrogen flow control system to work, and the core melt stabilization system and severe accident heat removal system.

So, and then after 12 hours they would utilize those non-safety related, shall we say, sprays. Because they are an important part of maintaining a long term approach to a safe stable state.

CHAIR POWERS: And it seems to me that because we're working in severe accident space at this point that there is no reluctance to grant them that their spray system is likely to be functional. And barring something that --

MR. FULLER: You would certainly hope that it's going to be functional, and you certainly hope they're use it, yes.

CHAIR POWERS: Barring something that makes failure of those system unequivocally follows directly from the accident phenomena.

MR. FULLER: Right. Right.

CHAIR POWERS: And of course one of those things, I mean you've mentioned debris dispersal into the sections and things like that, that raises a question about that that we need to explore a little bit. But otherwise, I mean the fact that the spray system is not declared a safety system relates more to the Chapter 15 analyses and not to the Chapter 19 analyses. And in Chapter 19 we're perfectly willing to give you condition credit on that system. I mean, it seems to me that's the way I look at things.

So I took my shot and you rebuffed it nicely.

MEMBER RAY: Maybe we should discuss it another time, Dana, if we're being consistent here. Because I'm declined to agree with what Bill said, which is the most likely cause of this catastrophe is==

CHAIR POWERS: Yes, absolutely. If you're initiated by the seismic event and that guarantees that you failed, despite independent event and became multiplied probabilities and we're stopped. Okay. Fair enough.

MR. FULLER: Okay. Let's go to the next

slide. So what we wanted to do is we know that AREVA really wants to do this right. They told us that, and they're giving us information that it suggests to us that the ultimate goal would be reached. But that's only half of the battle. The other half is to make sure that the COL applicants get this information in a timely way and start using it to put together their emergency operating guidelines, EOPs, SMAGs, training in the use of these. So we've asked them to provide a means to assure that.

So we requested them to identify a COL action item that would basically have the COL applicant provide us some documentation of the severe accident management technical basis, which of course they would get from AREVA. So that was our first question.

So we asked the follow-up question, Question 19-243. So I'll go to the next slide, slide 91.

And we asked them to elaborate. So what they did is they did send at that point the detailed. So if you look at the response to this question, and go into the file, you get a nice long attachment which is their first crack at the OSSA technical basis documentation. And in addition, in the RAI response they provided these words for a COL information item that are recorded in this sub bullet. So that they're saying that the COL applicants would reference -- will develop and implement the guidelines prior to fuel loading using the OSSA. And basically we want this to appear in the version of the FSAR, Chapter 19. And so that they say they'll put it there, and we're waiting for the next revision to make sure it's there.

Since I wrote this slide we have completed our first crack through the OSSA review. We've participated with our regulatory cohorts in Europe because they are either going to get their versions of OSSA or already have. And we actually had a meeting with them about three weeks ago in which we went over what we got from AREVA and what IRSN got from EDF, which they got from AREVA. And what the British hope to get and what the Finns hope to get.

And so we put our heads together and got a much better understanding of the breadth of what OSSA is going to be. And so we discussed some of these detail questions that would arise out of our review with them and got some additional ideas. We prepared a set of follow-up questions which, they've been sent now, right?

MR. TESFAYE: I think everything that's in my inbox has been sent.

MR. FULLER: So we have received this package of about 15 or 20 questions.

MEMBER SHACK: Man with a clean inbox. I'm impressed.

MR. FULLER: That's as of this morning.

CHAIR POWERS: You do not want to get on his distribution list, that's all I can say.

MR. FULLER: Okay. Let's go to the next slide.

So our approach is that we'd review accident management plans at the COL stage and audit each COL applicant to ensure that the would have the commitments in place and intend to meet them. And provide a means of systematically assessing, enhancing and maintaining their accident management capabilities consistent with our guidance and our agreement between the nuclear industry and the NRC that's in NEI 91-04.

And COL applicants should develop their plans based on the final as-go plant. You know, obviously we cannot give them a COL until -- we would give them a COL before they had their final procedures in place and training in place, obviously. But we want to make sure that they bought into the path towards making the correct ones.

CHAIR POWERS: Yes. It's like our stage 3.

MR. FULLER: Okay. Finally, I have a couple of slides on severe accident mitigation design alternatives.

You know, the main reason for this in design certification space is to satisfy the NEPA requirement arising from the Limerick action way back when. And so they have to do this, our regulations require that the design certification application has to produce an Environmental Report, which is no and no less than the SAMDA evaluation. The Environmental Report is the SAMDA evaluation, okay? And AREVA did that. And ANP-10290 Rev 1 is their latest versions of that.

We saw the original versions, had questions, they responded to the questions and on that basis revised that report.

Basically in the report they conclude that because they really have gone out of their way to put these radical by current plant standards severe accident mitigation features in their plant, that there isn't much else they can do. They couldn't find anything that was cost beneficial.

Nevertheless, we just for the record we gave them some comments and asked them to comment pertaining to some of the assumptions made in the cost benefit assessment they did. For example, they question point estimate core damage frequencies and not mean values. And we asked them to do mean values. They did.

And then we did identify some shortcomings in that initial response. Asked them some follow-up questions. And to make a long story short they basically addressed all of those subsequently.

And so we have no more open items on the SAMDA.

So let's go to the last one, our conclusion.

MR. TESFAYE: Previously?

MR. FULLER: Page 94.

MR. TESFAYE: Ninety-four.

MR. FULLER: Sorry.

So in summary we find that they meet our requirement. RAI questions have been resolved and there aren't any open items associated with SAMDA or the Environmental Report.

We did have more conservative estimations of what the maximum benefit would be than they did. But, still, nothing comes close to being cost beneficial. So even those that do come relatively close, we don't feel they need to include in their design. And we didn't ourselves uncover any additional design alternatives that they should have considered.

With that --

CHAIR POWERS: Look --

MR. FULLER: Pardon me?

CHAIR POWERS: Did you consider the alternative between using PAR and using spark igniters

MR. FULLER: No. They've already got PARs in their design. You have to do this as basically a delta to the design you're reviewing.

CHAIR POWERS: So there's really no benefit, so it didn't matter what they cost?

MR. FULLER: Yes. Now if they had meter in there, now we're talking a different story.

CHAIR POWERS: Yes. So it's really that if you can't define a benefit, unless you find something about the PARs just makes them not work and either from the get-go, all right, some portion of the accident --

MR. FULLER: Yes.

CHAIR POWERS: -- there's no benefit to be gained.

MR. FULLER: Now I imagine, I don't know

what their thought process was, but I imagine back when they were first considering what they were going to put into this design, they probably evaluated PARs and igniters both.

CHAIR POWERS: PARs have the wonderful feature that you don't have to have power to them. And furthermore, they work at even relatively modest levels of hydrogen, typically between one and two percent hydrogen you get recombination --

MR. FULLER: So we know what we you would have chosen.

CHAIR POWERS: No. I myself don't know. I mean, I'm very attracted to PARs, but I do know that the down side is that they poison, and they poison unless one's careful, during normal operating procedure. Paint something, the organic gets on them and they coat and things like that. And in a previous life, like you I had a previous life, I look a degradation of catalyst surfaces as a function of environmental considerations. And yes, I mean catalysts are wonderful things but you can irreversible or reversibly poison them.

MEMBER SHACK: Yes. I remember you raised this issue I think 15 years ago when Mike Snodderly was doing some initial analysis. It comes up every time somebody mentions it now.

I'd like the staff to come up with a definitive --

CHAIR POWERS: In other words, shut up.

MEMBER SHACK: It's one of those perennial issues that come up.

CHAIR POWERS: Boiling of pants off you, huh?

MEMBER SHACK: Well, no. I just added to my little list of responses. Remember you put together one time --

CHAIR POWERS: Yes.

MR. TESFAYE: I think that's all we have. If you don't have anymore questions of the staff.

CHAIR POWERS: Very good. Do we have any questions that people would like to pose to the speakers?

And here's our situation. My feeling is that we're still struggling a little bit, not with getting through Chapter 19. We have PRA expert out exploring the details, plowing into the details, plunging into the details and then we'll be interested to hear what he has to come back with.

In this particular area I know -- it's a lot of a situation of no good deed goes unpunished here. That indeed, the applicant has struggled heroically to come up with a way to accommodate severe accidents in a way well beyond what any existing plant does. And they have done quite a lot here. And, of course, to assure that they're not too content we raise a lot of questions on these.

My own feeling is that out of this questioning we've identified a couple of areas where there is some crucial behavior that we need to assure. That is we need to understand how the system depressurizes, that it depressurizes, how far it depressurizes and what to my mind the consequences of that is, is really do we rattle the vessel around enough to cause penetrations to the vessel so we get a prompt leak out of there. And we need to assure ourselves the PARs will function as designed. And apparently we will hear about that when we go into Chapter 6. And I'm perfectly willing to wait for doing that. Because I think we understand well how the PARs interface with this severe accident analyses.

I myself see a credible analysis of the progress of accidents. We did not go into a lot of the details of the core degradation process, and as Ed has pointed out there are questions in that area on the extent of core degradation at the time of vessel failure which is an area of discrepancy between the MAAP code and the rest of the world that MAAP tends to melt down cores very completely and quickly, and probably is an element of conservatism in there. For anything we've learned that's what conservative in one aspect of an accident may not be conservative in another aspect. So there could be differences there. And apparently that's one of the questions to be resolved. And I think there is a pathway to resolve that. I don't have any troubles letting that move forward.

See, the question of how a seismic initiator effects this system I think is an open question.

MEMBER SHACK: When are we going to hear about the seismic margins analysis? I mean, I'm not really saying this should be a Class 1 seismic analysis --

CHAIR POWERS: No, no.

MEMBER SHACK: But that you got to have a seismic margin of 1.67.

CHAIR POWERS: You think so?

MR. XU: We discuss about that on the last-- we discussed that last time.

MEMBER SHACK: We did that already? Did

we do that system-by-system? Okay. I missed it.

MR. XU: There's a 19.1 --

CHAIR POWERS: Well, it remains unclear to me how this system is effected by it.

And the other area that, you know. we need incorporate progression and if they get their melt densities wrong and things like that, but I think we understand that that's not going to make a qualitative change in things. It may change the quantitative nature of things and whatnot. You know, the system seems to be robust to those criticisms.

I come away not very confident in an understanding of what the radionuclides behavior is in these accidents. Now a lot of that will get clarified when we go into the Chapter 15 analysis because I assume there are similarities in the modeling and we can think about doing it in connection with Chapter 15.

Those are kind of my gross -- I mean, I got lots of detailed things. But those are the things that I see as making a qualitative -- you know, how we access this thing qualitatively. Which is really what we're doing here. I mean, we're in accident space and we're not asking them for 95 percentile things and whatnot. Yes, it's to get a feel for things.

Qualitative is pretty good here in this area, but it's the radionuclide I don't come away with a good qualitative feel on how that is handled.

Bill?

MEMBER SHACK: If I'm assured the SAHR has a 1.67 seismic margin --

CHAIR POWERS: That's not a threat, Bill, or is that a --

MEMBER SHACK: Add that to my flaw distribution.

CHAIR POWERS: Mike?

MEMBER RYAN: I am good. Thank you.

CHAIR POWERS: Sam, you've asked for some specific things.

MEMBER ARMIJO: Yes. Mainly because I haven't done my homework, I'm sort of a guest member of this Subcommittee.

CHAIR POWERS: An honored member of the Committee.

MEMBER ARMIJO: Thank you very much.

But anyway, first of all, I think the systems that AREVA has designed really go into a space where we've never been and addressed accidents in a way that no existing plant does. But we're all engineers and whatever you put in, we all want to make sure they work.

And in the case of the SAHRs and the core melts, the stabilization system to me the most important thing is to make sure that the cooling water lines that cool that core plate and ultimately flood the spreading room actually don't get blocks. Of course, in Bill's seismic event or somehow work in some degraded way so they don't put in as much water. Yes, you have two lines but what if each of them is not working quite. So I don't have a feeling for the margin in the system.

Obviously, if everything works like it's supposed to we shouldn't even be wasting time. But that's an area where I'd like to learn some more. I'd like to learn a little bit more about the ceramic materials, the zirconia. I think I asked a question on that.

That's all I have.

MR. WIDMAYER: There's an RAI that we'll get to.

MEMBER ARMIJO: Right. Right. And I asked the question a little bit more about cast iron is something that I learned about as a young metallurgist many, many years ago. And I thought it had just --

MEMBER SHACK: It had just come out.

MEMBER ARMIJO: And there's brittle cast iron and there's -- cast iron. I don't know if this is welded. So any document that describes that system a little bit more.

MEMBER SHACK: It's a big hunk of cast iron.

MEMBER ARMIJO: It must be.

MEMBER SHACK: Because that's a big room.

MEMBER ARMIJO: So I'd just like to get a copy of that.

CHAIR POWERS: Well, just understand that it has some advantages over the bronze you're used to.

MEMBER ARMIJO: So anyway, the request is any other information, a topical report or something like that, a technical report on these materials would be of interest to me.

MR. TESFAYE: We will look into that.

MEMBER ARMIJO: Thank you.

CHAIR POWERS: Harold?

MEMBER RAY: You've captured everything.

CHAIR POWERS: Okay.

John?

MEMBER SIEBER: I guess the only thing that sort of struck me quantitatively as opposed to quantitatively is the idea that somehow or other in the whole core assembly the way it is operating I still have to decide whether there is a potential for a steam explosion or not. And I have to do some more research, but maybe somebody can assure me at the full Committee meeting that they have looked at all the various aspects that would cause me, and they tell me that it can't happen.

CHAIR POWERS: If they can do that, we will be praying to them shortly afterwards. The disability of steam explosive is vanishingly small.

MEMBER SIEBER: Yes, but it just seems to me the potential is there.

CHAIR POWERS: Yes.

MEMBER SIEBER: Okay.

CHAIR POWERS: You bring up a good point, though, John. The ACRS at it's last meeting has indicated they're giving substantial discretion in the future to the subcommittees to decide when they bring things forward tot he full Committee. And I intend to take liberal use of that discretion. Because especially and quite frankly in connection with this plant we're not getting a lot of issues that require the wisdom and judgment of the full Committee as a whole. And so I am moving in the direction of the amount of time that we spend in front of the full

Committee. And my preference, my personal preference is to come before the full Committee when we say we have moved from this stage to the next and focus on why we think we can move to the next. But I am going to leave that discretion open to input both from the staff, the applicant and the members of the Committee that is if there are points at which you think it would be useful short of that milestone to bring things forward to the full Committee.

And one of the candidates is that when you have -- I think we're going to need another meeting on Chapter 19 just to tie all the bows and get the inputs from our experts and things like that, and round out some of the issues here.

One of the possibilities is Chapter 19 might be one to take forward to the full Committee, and so I toss that out. And I'm certainly open to suggestions from everybody on that regard.

But otherwise, my intention with this reactor is to until we run into what I would call significant issues in the process -- there always could be issues and things like that, but the way it's organized now it really didn't come to us until things are going to be pretty well resolved and there's not much to tell the full Committee. The exception, of course, is this Chapter. Another Chapter that might be a candidate would be 15 just because its figured so prominently in the regulatory process. I toss that out.

MEMBER SHACK: Yes.

(Member Shack gesturing ten.)

CHAIR POWERS: Of course, unavoidable there. But that keeps getting pushed back farther and farther in time.

Any other comments people want to make?

Well, it's been a very enjoyable session. I think you very much for your presentation. It was a heroic job. And one of these days you'll get the met density properly set.

MEMBER SHACK: He gives us a 95/95 and we still complain about it.

CHAIR POWERS: Yes, because he didn't take into account correlations. And he keeps using that ridiculous Pearson linear correlation instead of a decent one like a Kendal Tau.

MS. MROWCA: Dr. Powers?

CHAIR POWERS: Yes, sir.

MS. MROWCA: This is Lynn Mrowca and I have a question for you what you said before about meeting again Chapter 19. I guess it would help us maybe to understand if there are specific issues that you want to talk about. And for our schedule, I was wondering if you're talking about, and right now we move on to Phase 4 which is where we take our safety evaluation with open items and close them. So are you talking about sometime in that time frame?

CHAIR POWERS: You ask me to remember calendars -- no, I think we just need to find a time that we can meet to go over again. I mean, we did not finish the PRA itself. I think I have raised some questions about the severe accident analysis, especially radionuclide behavior, the seismic issue remains open to us. And I think we just need to round those out.

And quite frankly, it's a question of scheduling. I know that's a problem because right now the members are covering way too many systems all at once. So finding the time is a chore. And so that's why you get the big bucks.

MS. SLOAN: Dr. Powers, I guess I had a similar question. Is the meeting you're talking about on Chapter 19 a meeting in addition to like the Phase 5 type --

CHAIR POWERS: Yes. It's much like this meeting, except we will give you a list of questions that we're trying to address. And if you come back to us and say we would prefer to address this in connection with another chapter, I think that's okay.

Quite frankly, I mean to all concerns, staff and applicant both, this is going smoothly enough that I don't have trouble moving things among chapters. I'm not encountering a difficulty with that myself, and I'm not hearing from any of the members of the Subcommittee have difficulties shifting from one chapter to the other. If you'll put up with our seemingly foolish questions because we've gotten confused from chapter-to-chapter, you know. And if you do find that frustrating, you know let me know and we'll make a more rigid structure for those.

Yes, I'm willing to work very collegially on this process right now. Because I see excellent intentions on the parts of both. I mean I truthfully believe the staff is tried to do a heroic job on this. I know the applicant is trying very hard to do a technically responsible job here. So I'm willing to work you guys very collegially, in both parties, on scheduling and what we cover and things like that. And if you think we're not being specific enough in what we're asking you to present -- you'd be surprised how thick my skin is and my ability to tell you that's why you get the big bucks, too.

Okay. Any other comments that people would like to make?

Well thank you very much.

Again, congratulation to all. I think you're gone well beyond what's required of you.

(Whereupon, at 4:43 p.m. the Subcommittee meeting was adjourned.)