UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

January 10, 2012

MEMORANDUM TO: File

FROM: Sherry Meador **/RA/**
ACRS

SUBJECT: CERTIFICATION OF THE MEETING TRANSCRIPT FROM THE ADVISORY COMMITTEE ON REACTOR SAFEGUARDS EPR SUBCOMMITTEE MEETING HELD ON AUGUST 18, 2011 IN ROCKVILLE, MARYLAND

The transcript of the subject meeting was certified on January 3, 2012 as the official record of the proceedings of this meeting. A copy of the certified minutes is attached.

Attachment:
As stated

Official Transcript of Proceedings

NUCLEAR REGULATORY COMMISSION

Title:	Advisory Committee on Reactor Safeguards US EPR Subcommittee: Open Session
Docket Number:	(n/a)
Location:	Rockville, Maryland
Date:	Thursday, August 18, 2011
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NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

U.S. EPR SUBCOMMITTEE MEETING

OPEN SESSION

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THURSDAY

AUGUST 18, 2011

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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 8:30 a.m., Dana A. Powers, Chairman, presiding.

COMMITTEE MEMBERS:

DANA A. POWERS, Chairman

SANJOY BANERJEE, Member

MICHAEL T. RYAN, Member

WILLIAM J. SHACK, Member

JOHN W. STETKAR, Member-at-Large

NRC STAFF PRESENT:

SURINDER ARORA, NRO/DNRL/NARP
JAMES BONGARRA, NRO/DCIP
JASON CARNEAL, NRO/DNRL
JOE COLACCINO, NRO/DNRL
TANYA FORD, NRO/DNRL
FRED FORSATY, NRO/DSRA

MICHAEL JUNGE, NRO/DCIP

SHANLAI LU, NRO/DSRA/SRSB
MICHELLE HART, NRO/DSER
GETACHEW TESFAYE, NRO/DNRL
CHRISTOPHER VAN WERT, NRO/DSRA
DEREK WIDMAYER, Designated Federal Official

ALSO PRESENT:

KENT ABEL, AREVA NP

RICHARD DEVENEY, AREVA NP

DARRELL GARDNER, AREVA NP
LISA GERKEN, AREVA NP
GREG GIBSON, UniStar
JOHN N. HAMAWI, AREVA NP*

JERALD HOLM, AREVA NP
TIM KIRKHAM, UniStar*
DOMINICK LOGALBO, AREVA NP
GENE MOORE, AREVA NP

ALSO PRESENT:
C.K. NITHIANANDAN, AREVA NP
DESMOND RAYMOND, AREVA NP
DON ROWE, AREVA NP
ROBERT SALM, AREVA NP
LILIANE SCHOR, AREVA NP
SANDRA M. SLOAN, AREVA NP

*Present via telephone

C-O-N-T-E-N-T-S

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

8:28 a.m.

CHAIRMAN POWERS: The meeting will now come to order. This is a meeting of the Advisory Committee on Reactor Safeguards U.S. EPR Subcommittee. I'm Dana Powers, chairman of the Subcommittee. ACRS members in attendance are Sanjoy Banerjee, William Shack, Michael Ryan, and I think Mr. Stetkar is --

MEMBER STETKAR: He is.

CHAIRMAN POWERS: Going to join us at his leisure. The purpose of the meeting is to continue our review of the SER with open items for the design certification document submitted by AREVA NP for the U.S. EPR design, and the SER with open items for the combined operating license application submitted by UniStar for the Calvert Cliffs Nuclear Power Plant, Unit 3.

We will hear presentations on and discuss Chapter 15, Transient Accident Analysis, Section 15.6.5, and Chapter 18, Human Factors Engineering of the DCD SER. In Chapter 15, Transient Accident Analysis, the COLA SER. My understanding is especially the transient accident analyses, it's going to be a fairly lengthy set of presentations. So to be forewarned is to be forearmed.

The Subcommittee will hear presentations by and hold discussions with representatives of AREVA NP, the NRC staff and other interested persons regarding these matters. The Subcommittee will gather relevant information today and plans to take the results of the review of these chapters, along with other chapters reviewed by the Subcommittee through the full Committee at a future full Committee meeting to be determined.

There will be lengthy. I don't think we should be deterred from exploring these subjects fairly thoroughly, and then try to get them resolved to the best extent we possibly can. I understand that at least part of this meeting is going to be closed to protect some proprietary information that seems to be staring me in the face right now.

Do we close right -- do we need to close right away, or we are going to -- my schedule has us open for a while, and then closing.

The rules for participation at today's meeting have been announced as part of the notice of this meeting, previously published in the Federal Register. We have received no written comments or requests for time to make oral statements from members of the public regarding today's meeting.

A transcript of meeting is being kept on Bandit, available as stated in the Federal Register notice. Therefore, we request that participants in the meeting use the microphones located throughout the meeting room when addressing the Subcommittee. The participants should first identify themselves and speak with sufficient clarity and volume so they may be readily heard. Copies of the meeting agenda and some of the handouts are available in the back of the meeting room.

We do have a telephone bridge line, and I understand we have participants from AREVA NP and Unistar online. Periodically during the meeting, we request the participants on the bridge line identify themselves when they speak, and to keep your telephone on mute during times when you're just listening. Do members of the Subcommittee have any opening comments they would like to make?

(No response.)

CHAIRMAN POWERS: I don't see any opening comments. Getachew, want to open up our discussion here?

MR. TESFAYE: Yes, Mr. Powers. Thank you. Good morning everyone. Again, my name is Getachew Tesfaye. I'm the NRC project manager for AREVA U.S.

EPR Design Certification. Today, we continue our Phase 3 ACRS presentation of the staff Safety Evaluation Report with open items.

For the record, I'll briefly summarize our Phase 3 activities. To date, we have completed the first three presentations of 12 of 19 chapters. We presented Chapter 8, Electric Power, and Chapter 2, Site Characteristics, on November 3, 2009, and Chapter 10, Steam Power Conversion System and Chapter 12, Radiation Protection, on November 19, 2009.

On February 18 and 19 of 2010, we presented Chapter 17, Quality Assurance and portions of Chapter 19, Probabilistic Risk Assessment and Severe Accident Evaluation. On March 3rd, 2010, we presented Chapter 4, Reactor, and Chapter 5, Reactor Coolant System and Connector Systems.

On April 6, 2010, we presented Chapter 11, Radioactive Waste Management, and Chapter 16, Technical Specifications. On April 8, 2010, we briefed the ACRS Full Committee on the seven chapters that were completed through March 2010. On April 21, 2010, we completed the Chapter 19 presentation. Also, on April 21, 2010, we received a letter from the ACRS Full Committee chairman on the seven chapters that were completed through March 2010. The letter stated

ACRS has not identified any issues that merit further discussion.

On May 27, 2010, the staff submitted its reply to ACRS. On November 30, 2010, we presented Chapter 13, Conduct of Operation. On February 7 and 8, 2011, we presented Group 1, sections of Chapter 15, Transient and Accident Analysis. Please note for Phase 2 and 3 reviews, Chapter 15 sections are broken up into two groups.

On March 23, 2011, we began the Chapter 15 Group 2 presentation with the realistic large-break LOCA topical report presentation. On April 5, 2011, we presented Chapter 6, Engineered Safety Features. Today, we will present Chapter 8, Human Factors Engineering and plan to complete Group 2, Chapter 15, Transient and Accidents.

On November 14 and 15 of this year, we plan to present Chapter 7, Instrumentation and Controls and portions of Chapter 9, Auxiliary Systems. Our current schedule for completing Phase 3 presentation is February 2012. That completes my prepared remarks, Mr. Chairman.

CHAIRMAN POWERS: What was that meeting for the next --

MR. TESFAYE: The next one? November 14-

215, Chapter 7 and Chapter 9.

CHAIRMAN POWERS: Okay, because that may get changed.

MR. TESFAYE: Okay. I might add, that has not been confirmed from you? That's what --

CHAIRMAN POWERS: Yes. I think there's a very likelihood that that will be changed. I don't know when, but very high likelihood that that will be changed. Okay. Darrell, are you ready to go?

MR. GARDNER: Yes sir.

CHAIRMAN POWERS: Okay. Mr. Darrell Gardner will head up his team of elite professionals, to discuss the wonderful world of human factors engineering, and you'll tell us when you need to close the meeting?

MR. GARDNER: Yes sir. Thank you, Dr. Powers. Again, my name is Darrell Gardner, Director of Licensing for the EPR at AREVA. This morning, we're going to present to you Chapter 18, Human Factors, and our presenters this morning are Desmond Raymond and Dominic Logalbo. We have some support staff and if they're called upon to answer, I would ask that they announce their names and provide the support requested.

A portion, as you mentioned, of this

meeting, we're asking that it be closed to the public. I think that we can get through the first few slides of this, and depending on the member questions, we can keep it open. But at about Slide 10, we start presenting proprietary material, and again, depending on member questions, the material could be proprietary.

This chapter is based on a series of specific detailed implementation plans submitted by AREVA to the staff for review, and those implementation plans were proprietary.

CHAIRMAN POWERS: I would just border on let's be conservative on that, and border on the cautious, and then we can decide later if we need to change our mind on that.

MR. GARDNER: Certainly. So I guess we're ready to kick it off, Desmond. Just again, if you see some proprietary work, ask to close the meeting.

MR. RAYMOND: Okay. All right, good morning. My name is Desmond Raymond. I certainly appreciate the opportunity to present the design certification for Chapter 18 to the ACRS.

CHAIRMAN POWERS: It is considered bad form to suck up at the Committee in your opening statement.

MR. RAYMOND: Okay, great.

CHAIRMAN POWERS: We doubt seriously that you appreciate this opportunity.

(Laughter.)

MR. RAYMOND: A little bit about myself, my background. I have a Bachelor's of Science in Chemical Engineering.

CHAIRMAN POWERS: All right.

MR. RAYMOND: And Physics from --

CHAIRMAN POWERS: Neither of which qualify you to discuss Human Factors at all.

MR. RAYMOND: From Georgia Tech.

CHAIRMAN POWERS: He's not here, so it doesn't -- you can't suck up to him here.

MR. RAYMOND: I got my Master's degree from the University of Tennessee in Engineering Management. I have a PE professional engineering license in the states of Tennessee and North Carolina that are currently active. I started in the industry at the Defense Waste Processing down at the Savannah River site. I was a process engineer, and then went to a utility for about eight years doing I&C modifications.

Did a couple of control room mods for the Tennessee Valley Authority, and then about five years ago, I came to AREVA to start this effort on Human Factors licensing.

CHAIRMAN POWERS: What units did you modify at TVA?

MR. RAYMOND: I did some mods at Sequoia and Watts Bar, and some non-control room mods at Brown's Ferry.

CHAIRMAN POWERS: Okay. You've definitely earned your spurs.

MEMBER STETKAR: By the way, he qualifies to be a Human Factors engineer because he seems to be a human.

MR. RAYMOND: I surround myself with a lot of smart people.

CHAIRMAN POWERS: That's why Sloan is not up here.

(Laughter.)

MEMBER STETKAR: And she will be later.

CHAIRMAN POWERS: Go ahead.

MR. RAYMOND: Okay. Here's the 12 elements that are laid out in 711. Our program follows these 12 elements. I'm not going to go through these in detail here, but throughout the presentation, we'll discuss each elements that's in NUREG 0711. Our U.S. EPR HFE program meets the criteria in NUREG 0711 Rev 2, as endorsed by the Standard Review Plan, Chapter 18.

There's nine implementation plans that discuss the various elements of NUREG 0711. Those have all been submitted to the NRC staff for review, and the NRC approved the HFE program, as managed and executed by the COLA applicant.

Here's an overview of our program. It's a systematic top-down approach, starting from the requirements from the design certification, trickling down to the analysis phase, which includes the functional requirements analysis, operating experience, human reliability analysis and task analysis.

We do get some inherited information with respect to lessons learned from OL-3 in Finland and Taishan and the EPRs that are in construction. We apply those into the operating experience lessons learned database, and apply those appropriately to our design. Once we get done with our analysis phase, we get into our design phase. What you see here is the second block down, second gray block rather, and from that, we go once the design is done, we get into V&V.

You can see the dotted lines on the right side show the iterative nature, and I think show the relationship between the different elements and the activities that take place for the design process. So the first element is the program management. The objective of this goal is to establish that plant personnel can easily access required information and controls, to safely and effectively monitor and control the plant, processes and equipment.

CHAIRMAN POWERS: You said effectively. Your slide says "efficiently."

MR. RAYMOND: I misspoke.

CHAIRMAN POWERS: And I wondered -- when I read the slide, I wondered how do you measure efficiency in this context? Maybe you didn't mean that. It was just the effectiveness, is what you really meant, and it has nothing to do with efficiency. But if I read the slide, it says "efficiently," and I did not know how one measures efficiency in this context.

MR. LOGALBO: I haven't introduced myself yet. My name is Dominick Logalbo. How we would measure it in the context of the control system is how easy it is to access data. Given an event, how easy it is to use the presented information to understand, diagnose and develop plans of actions, which is we would view that, gather that data, integrated system validation, part of V&V, but also during task analysis and design implementation.

It's also gathered subjectively by talking to the operators and asking for their perspective on how easy or hard it is to gather, interpret and use information.

MR. RAYMOND: And you'll see when we get into the task analysis the relationship between the design and doing the evaluations, like workload assessments, to verify high workload situations or areas when functions need to be reallocated, so the operator isn't overburdened, those types of things.

The scope of the program includes the main control room, remote shutdown station, the technical center, risk-significant local controls, with HFE guidance provided to the rest of the design activities for the rest of the plant. The HFE organization placement and authority is they followed the same design process as all the other disciplines. They do design reviews for applicable designs to -- applicable design requirements for the control room and the HSIs in those locations.

Any issues that are identified are documented in the Issues Tracking database. It's an HFE Issues Tracking database that's maintained throughout the design process, and you can get additional details in the U.S. EPR program management plan.

Here's a relative schedule, an implementation schedule of the various activities that take place. The elements are program management and operating experience. Obviously, it is continuous throughout the design process. As OE comes in, those get applied to the design immediately.

You can see the waterfall and functional requirements analysis, HSI design, staffing and qualification. Once the design gets done, then we start HFE V&V, and then design implementation and human performance monitoring.

MEMBER STETKAR: Desmond, before you -- this is a nice relative schedule, and in absolute terms, where are you today on this schedule?

MR. RAYMOND: Well, considering that the detailed design activities are relatively limited, I would say that we're over here in the concept phase. I actually have some concepts that I'm going to show you --

MEMBER STETKAR: It's kind of interesting, because I read an awful lot in your project plan, which kind of just parrots back the requirements, that a lot of these tasks are very vital to be implemented very early in the design phases, so that the design receives efficient feedback from the human factors engineers.

For example, the requirements analysis, the preliminary task analysis. There's a lot of emphasis on getting that stuff started early. Last I checked, AREVA was building two of these things over in Europe. It strikes me that our control room in the United States probably won't look dramatically different from those control rooms.

CHAIRMAN POWERS: Well, at least if I look, it is there. There seems to be relatively little feedback into the hardware aspects of it.

MEMBER STETKAR: In principle, they're supposed to be.

CHAIRMAN POWERS: They're supposed to be, but if you look at the chart, it's --

(Simultaneous speaking.)

MEMBER STETKAR: No. It's presented as a very reactionary type. We've got the design. We're going to figure out how well the operators can work around it. Whereas the process says a lot of these factors should be started very, very early, so that you can have feedback into the hardware design and configuration.

So it strikes me that you haven't really started anything yet. You have a plan that sort of regurgitates all of the good features that you have to regurgitate for a plan. You haven't done anything yet at all?

MR. RAYMOND: Well, we have done some task analysis.

MEMBER STETKAR: Given the fact that you're building two, the company is actually building two of these things, did you do any of this for either of those two?

MR. RAYMOND: The ones that are in Europe and ones in --

MEMBER STETKAR: Well, the two that are under construction, at least, you know, fairly well people projecting completion dates, you know, that are measurable?

MR. RAYMOND: This was done -- from my understanding, this was done in not a documented way that we could say this is 0711 type of document standards. The availability of the information is somewhat limited because they're not under the same requirements with how things need to be documented.

But you know, we did actually try to go

down that path at one time, and we couldn't get the available documentation.

MEMBER STETKAR: Couldn't get the available documentation of the design that's already pretty well in place there, so that you could use that as a starting point for some of your initial functional requirements for this design, the task analysis I mean?

MR. RAYMOND: I think --

MR. GARDNER: If we flip back a few pages to look at that overview slide, you'll see that there's a portion of that that talks about the figure on the left that talks about the inherited information, that's a consideration of those previous design elements. I think the point here for the purposes of design certification and satisfying the guidance, the implementation plans describe how this would go forward.

I think it's fair to say there's been some work already done in these areas, which establishes that box.

MEMBER STETKAR: That's what I was asking what you have done, because I understand the strategy and the allowance in the regulations to be able to push off completing this task until well after formal reviews of the DCD and the COL are completed.

On the other hand, I've got kind of an interest that the control room is actually designed pretty well for human factors considerations, which means you really ought to start this process soon, regardless of what the licensing strategy may be for, you know, final documentation of the process.

I hate to be so cynical, but if you were dealing with a paper design that had absolute, you know, was brand new, and had just vague concepts of what it might be, I could sort of understand why you might be floundering a bit in terms of getting started.

But in this particular plant design, you're not, you know. You have experience from the European, the Convoys and N4 designs that preceded European EPR designs, and you have two plants that are under construction, well underway under construction.

So it's sort of surprising that you haven't made any initiatives to actually start this process, to see whether a more formal approach that follows NUREG 0711 indeed might provide some important lessons learned, can feed back into the U.S. EPR control room design, or some of the local panels, if that's the way it works out, in a timely manner.

Rather than waiting until the design is finished and saying okay, now we know everything about the hardware and we can figure out whether the humans can work within those constraints.

DR. SLOAN: This is Sandra Sloan from AREVA. Just to be clear --

MEMBER STETKAR: I'll end my monologue now.

DR. SLOAN: Yes. I understand what you're saying. Let me say two things. One is that we are always keeping up with what is being developed for the other projects. So what is going on for OL-3, we maintain a cognizance of, and we certainly will factor in any lessons learned from there, or to the extent we can, what we learn from Flamanville OL-3 or the project in China.

So those projects are moving on, and we're keeping tabs on what's going on there. I think all they're trying to say is simply where we are in the design process is what they're describing here. We're not going to argue with your point, because I would just say too that they are in kind of the same place as the overall detail design of the plant.

It's not like everybody's moving forward, madly designing all kinds of design detail without these guys on board. Everybody's moving together. It just may not be at the pace you expected.

MEMBER STETKAR: But Sandra, one of the important things that Desmond did say, that's a very valid observation, is that perhaps -- you said you're keeping abreast of lessons learned from those other plants, as the designs are moving forward and progressing.

One of Desmond's observations was that perhaps the human factors engineering aspect of those designs was not, I have to be careful here, as well documented or as comprehensive as you might eventually have, following this structured approach and the guidance in NUREG 0711.

So it's not clear that some of the human factors engineering insights, from following lessons learned from those designs, would necessarily help your process. In other words, you might not find those insights until operators finally try to operate the controls, and find out that gee, somebody really should have thought about this way back, you know, 15 years ago, when the design was being finalized and the plant was being constructed.

So I think there's a bit of a notion that if the others have not followed this type of systematic, comprehensive process, especially of trying to integrate the human factors engineering aspects of the design pretty early, during the construction phase you may know a lot about how the basic hardware configuration concepts are being developed, but you may not learn very many valuable lessons about the human factors part of that, if you follow my --

DR. SLOAN: Let me just make one comment. I would not say the process they've used is not systematic or documented. I would clarify that to say it's different. Not unlike other regulatory things, different doesn't mean less quality or something like that, and I'll just say too, that we have people imbedded on the OL-3 project for that reason.

Not just in the human factors area, but in many areas, feeding back lessons learned. I don't want you to get the idea that there's no documentation and they didn't have a systematic process. I want you to take away it's different, and it can't be taken one for one into the U.S. process and credited.

But the basic thought processes in how you go through that process are the same no matter where you go in the world.

MR. RAYMOND: The IEC standards, they

follow, have some different documentation requirements in structure. They're structured a little bit differently.

MEMBER STETKAR: Yes, but that's all hardware-related stuff. I'm talking about people dealing with --

MR. RAYMOND: I'm talking about the OE.

MEMBER STETKAR: I'm dealing, I'm talking about the OE; I'm talking about the evaluation that you do, that you'll eventually get into when I stop babbling here about the function, you know, defining the functional requirements in the context of the types of scenarios that the operators need to deal with, in terms of developing a task analysis methodology, in terms of doing some preliminary task analysis and so forth.

So you know, I'm less interested in the hardware evolution. I'm more interested in how the human part of the process gets factored in in an early stage, and without all the -- I've said it enough times. So I'll let you get going.

But I was hoping to hear that you were saying well, we've done some functional requirements analysis and we've done some preliminary task analysis, and somewhere in your relative schedule you'd be in the really purple boxes, rather than you know, way out on --

MR. RAYMOND: As part of the Calvert Cliffs detail design effort, we have done some pilots on the task analysis-functional requirements analysis, and operating experience-gathering. We piloted a few systems. We have done that. Bu t that work has kind of gone to a trickle at this point, so --

MR. GARDNER: I think what we want to do is separate out those things we needed to accomplish for design certification, versus those things you would accomplish as part of that detailed design effort, supporting a specific application.

MEMBER STETKAR: You know, I understand that, and I come back to we're in one of those three anomalies in the design certification world, where you're allowed in design certification space to not accomplish anything effectively before the COL is issued, other than to commit to have a program in place, provided the program follows, you know, basic NUREG 0711 and other guidance.

So you know, I understand what you can do in design certification space, and you're taking the approach that you're doing what you can do, you know, what you're allowed to do. I'm just trying to understand whether there's any progress in terms of doing what might be more than the minimum that's allowed.

MR. LOGALBO: This is Dominick Logalbo speaking. I just wanted to reinforce what Desmond said. Behind the implementation plans are work instructions, and we have piloted those activities. So --

MEMBER STETKAR: And you have done some of that work on the Calvert Cliffs, up to the point where it sort of slowed down?

MR. LOGALBO: Correct. So for the OER process, some work in PFRA are limited, plant functional requirements analysis, system functional requirements analysis, and task analysis.

MEMBER STETKAR: So some limited amount of those pilots have been done?

MR. LOGALBO: Correct.

MEMBER STETKAR: Okay. That's good news anyway. Thanks.

MR. RAYMOND: Operating experience review. It's a standard HFE approach. We gather operating experience from industry, non-nuclear industry and apply those to the HSI design. Pretty straightforward. You can get more detail in the operating experience implementation plans.

Functional requirements analysis and functional allocation. We just really need to close this. I think we would ask Dr. Powers to --

CHAIRMAN POWERS: Okay. They want to close this point.

MR. RAYMOND: We're moving into proprietary material.

CHAIRMAN POWERS: Do your thing. I'm closing this up.

MR. WIDMAYER: I don't have -- I'm not sure who some of the people are. You guys can help me out on this.

CHAIRMAN POWERS: Is there anyone here that shouldn't be here in closed session, I think, is the question.

MEMBER STETKAR: Also, we need to close the bridge lines to anybody that might be -- anybody in from the public, members of the public.

DR. SLOAN: I would phrase it in terms of is there anybody in the room not representing AREVA, UniStar or PPL?

MR. WIDMAYER: Or the NRC.

DR. SLOAN: Of course, obviously.

CHAIRMAN POWERS: And is there anyone on

the bridge line that doesn't represent one of those organizations?

MR. WIDMAYER: Nobody's running out, so --

CHAIRMAN POWERS: Okay, and we made the appropriate change in the transcript here?

MEMBER RYAN: Is the bridge line closed?

MR. WIDMAYER: I don't think it's closed. They're still open.

CHAIRMAN POWERS: Well, they want it open for some people.

MR. WIDMAYER: It should only be AREVA and UniStar on the bridge line. I didn't give it to anyone else.

(Whereupon, at 8:59 a.m., the above-entitled matter went off the record and resumed at 10:05 a.m.)

CHAIRMAN POWERS: Okay. So we can reopen the meeting.

MR. TESFAYE: That's correct.

CHAIRMAN POWERS: And let forth the throngs, the masses that have been waiting outside to barge in here or not, and Getachew is going to lead us or start us or do something with us.

MR. TESFAYE: Tanya Ford and Jim Bongarra will be presenting the staff's findings on Chapter 18.

Tanya.

MS. FORD: Thank you, Getachew. Good morning. My name is Tanya Ford, and I'm the project manager responsible for coordinating the Chapter 18 review for the U.S. EPR design certification application. I received my B.S. degree in Chemical Engineering from North Carolina Agricultural and Technical State University.

Prior to joining the NRC, I worked for Westinghouse in their Transient Analysis and Fluid Systems Groups. I joined the NRC in 2002, and have worked as a reactor systems engineer in both the Offices of NRR and NRO. As I mentioned before, I am currently the project manager in the EPR Projects Branch, and I am responsible for the reviews for Chapter 2, 17, 18 and 19.

Today's presentation will cover the staff's Phase 2 safety evaluation report for Chapter 18, and I would like to highlight that we have identified no open items.

The technical staff who supported this review include members of the Operator Licensing and Human Performance Branch. Jim Bongarra led, served as lead technical reviewer, and was assisted by Paul Perringer and Jacquan Walker. Michael Junge is the supervisor for this branch.

A total of 235 questions were issued to the applicant requesting additional information for Chapter 18. As previously stated, there are no open items, and tables that are identified on Slides 3 and 4 show the breakdown of the number of questions that were asked per section for Chapter 18.

At this time, I will turn the presentation over to Jim Bongarra, who will continue the Human Factors Engineering presentation for the staff.

MR. BONGARRA: Thank you, Tanya. I'm Jim Bongarra, as Tanya mentioned, and I'm an engineering psychologist in the Operator Licensing and Human Performance Branch of NRO. I have a Bachelor's and Master's degree in Psychology. I've been with the NRC since 1984, so I guess that qualifies me as being kind of a human factors fossil.

I've been with ONR, Office of New Reactors since its inception. I'm the lead human factors engineer and reviewer for the AREVA U.S. EPR plant. Previously, I was principal HFE reviewer for the certified Westinghouse AP-600 and AP-1000 designs, and I was also an HFE reviewer on the GEA ESBWR design certification.

Before joining Office of New Reactors, I was with the Office of Nuclear Reactor Regulation as a human factors engineering psychologist. I began working in the nuclear field in 1972, as a field engineer and a training coordinator with the Bechtel Power Corporation at various power plant construction sites and at headquarters in Gaithersburg.

From '78 to '84, I was an HFE consultant with the military, the government and nuclear power plants. This morning, I have three objectives in my presentation to the Subcommittee. They are to briefly outline the staff's evaluation process, discuss aspects of the Chapter 18 HFE review that the staff considers noteworthy, and to provide the staff's conclusions from our technical review.

Thank you, Tanya. This is just simply a representation of the staff's HFE regulatory review model. It's the process basically that's outlined in our standard review plan, Chapter 18, and it's explained in more detail in NUREG 0711. It's also the same process that AREVA followed, as they've already explained, to develop the U.S. EPR HFE program.

So I'm not going to go into detail on these elements again. But what's important is that the bottom line is, and Dr. Powers, I think you somewhat referred to this already, is that AREVA, in their process for Chapter 18, they followed this NUREG 0711 process. AREVA's HFE design for the U.S. EPR, in my opinion, didn't present the staff with any real substantive technical changes or challenges really, from what we would expect from an applicant for a new plant design.

The applicant's proposed HFE design process is pretty much, again by the book, which is not a bad thing at all. This is what we're looking for.

I want to emphasize here that this aspect, and I'm talking about in terms of by the book, is for the human factors engineering element. I'm saying that because there are, and they're very, if you will, unique aspects perhaps, that are more in line, sir, with what you were asking earlier about, in terms of I&C architecture that really forms the foundation of the HSIs.

So I don't want to over-emphasize the issue that it's, you know, kind of by the book, and there are very well made areas that are somewhat different for EPR. But from a human factor standpoint, everything's pretty straightforward.

MEMBER STETKAR: In terms of process, it's pretty straightforward.

MR. BONGARRA: Yes, in terms of process.

MEMBER STETKAR: It details, for example, the discussion that we had about identifying specific features that might be differently challenging for the operators when you do task analysis, within the context of this framework, become much more design specific, right?

MR. BONGARRA: Yes.

MEMBER STETKAR: Okay, thank you.

MR. BONGARRA: What I'd like to do for the members this morning, then, is to discuss, as I mentioned, a few noteworthy items of this review. These items in that visual are related to the highlighted process elements in the slide, namely human system interface design procedures, training and verification, and validation.

I'd like to discuss the items, starting with verification and validation. As we've seen here already from AREVA's presentation, and from past experience, verification and validation is perhaps the most important and the most complex element of the entire program, relative to the other program elements.

I'll then discuss how the staff has used lessons learned from recent design certification reviews and updated guidance, to review the applicant's minimum inventory of alarms, controls and displays. Then I'll explain how procedures and training elements were addressed as part of the EPR design certification review. Then I'll end with a review of the applicant's proposed use of computer-based procedures.

As this next slide indicates, we're going to talk about verification and validation. Because it's such an all-encompassing activity, the staff has always emphasized the importance of this step, the importance that it has in determining the success of an overall HFE program, and how necessary it is for the staff to evaluate the V&V activity, in order to make a safety determination for a design certification application.

Now for the EPR design certification, AREVA provided a very detailed methodology and implementation plan for conducting verification and validation, including well-defined and thorough sample scenarios that will be used to validate the EPR HFE design.

CHAIRMAN POWERS: I agree with every one of your conclusions up there. I mean they did a nice job on verification and validation and what-not. The question that comes up in my mind is they sample the scenarios, and they have enough of them.

I mean my eyes glaze over after a while. But I come away saying how do I know that they did enough? How do they know that that one thing that they did not sample is not the one that gets you at some point in the future?

MR. BONGARRA: Well, let me try and qualify the idea of sampling scenarios, as I've identified it in the slide. What I meant to say there was essentially that as part of the design certification submittal, what AREVA has done is they've provided us with a sample of scenarios. If I'm not mistaken, it was three or four scenarios that they have already developed, to give us an understanding of essentially how these scenarios, the ones that remain, will be developed.

So it was, you know, they were just providing us with a portion of an overall population, if you will, of scenarios that they will subsequently develop as a result of going through the overall HFE design process. It's expected, if they follow that process completely and correctly, that the remaining scenarios that they'll develop will cover that spectrum of tasks and operational conditions that will be satisfactory.

I mean we couldn't ask them to develop all of the scenarios that they possibly could come up with at this point in time. The design has not proceeded that far along to be able to do that. But we have --

CHAIRMAN POWERS: Even once -- I mean on the day they're ready to turn it over to the COL, they will have examined some sampling of things. Like you say, comprehensive is not possible, because I can come up with more scenarios than they can test in a lifetime, several lifetimes.

But so we're doomed to doing verification and validation on a sample. How do we know when that sample has been large enough?

MR. BONGARRA: Well, indeed, if the process itself is followed, we have confidence that the scenarios that will be developed, essentially cover the safety-significant conditions that might be presented during accident situations. We have in the overall process input from the probabilistic risk assessment, to give us an idea of -- give the applicant an idea of what safety-critical operator actions they need to ensure are part and parcel of the scenario.

Again, you know, it's not possible to come up with 100 percent of each, every type of condition that could possibly be faced under conditions of normal operations, for instance. But there's a hierarchy; there's a -- as part of the operational condition sampling process, there's an attempt to identify those scenarios that are risk-important, and are representative of the population of conditions. That's the best answer I can provide you with.

MR. JUNGE: This is Mike Junge. I'm the branch chief for Operator Licensing Human Performance. This is the initial, I guess I should put it, initial verification validation. The verification validation really continues with every operator license exam, and it will continue for the life of the plant.

So as we see during the exam periods, the examiners will find -- they might find a scenario that isn't covered, or there might be something missing. That will have to be adjusted, and it will be in the COL's HED process that will fix those areas. So this is almost a constant review of the verification validation.

0711 also describes certain criteria that have to be met in these scenarios. So that's why there are 25 to 50, as Dominick described, scenarios. They can't cover all the areas in one scenario. Well they could, but it would be one significantly long scenario.

(Laughter.)

CHAIRMAN POWERS: Well, the point you made is an excellent point, and speaks to the general defense indepth design that we have in the safety strategy. I'm looking at just this one, and still puzzled over how do I know I've done an adequate --

MR. JUNGE: And on top of that, we also are going to inspect. Since this is a DAC, we'll have inspection procedure, to make sure that we're satisfied with what they've done. But again, not everything is covered, and that's our hope in the scenarios, that the examiners come up with and the licensee comes up with, will find some of those things.

MR. BONGARRA: To continue on, Mr. Logalbo has already provided a description of the overall process in detail.

CHAIRMAN POWERS: He did an adequate job.

MR. BONGARRA: And so I won't repeat that. What's important to the staff here is that AREVA provided a significant level of detail in their verification and validation and implementation plan, well beyond a high level description, a programmatic description. So the staff is very pleased with the way AREVA did develop this implementation plan. They did a commendable job.

Verification and validation is identified here, and is important and noteworthy really for two reasons. One I've already alluded to here, and that is the robust treatment of this program element really has allowed the staff to make a safety determination based on a substantive methodology and not a high level concept of what the method would consist of.

So what this does is it also allows them, because this implementation plan is so detailed, it allows a subsequent COL applicant really to implement this implementation plan, implement the process, and not have to go back and really fill in the blank, so to speak. So again, this is a commendable aspect of the way AREVA has handled this verification validation element.

Okay. Onto the next item, minimum inventory. The concept of minimum inventory is part of the NRC's general resolution -- is part of NRC's general resolution to the level of control and design detail needed for design certification. The principle regulatory document that really addresses and explains minimum inventory is the SECY Letter 92-053, and it was issued in conjunction with the whole process of design acceptance criteria.

I'm not going to go into a lot of detail about minimum inventory, but what I will say is that minimum inventory is a set of alarms controls and displays that are needed by operators, to bring the reactor to a safe shutdown condition and to maintain it in a safe shutdown condition in the case of an accident, where manual operator actions are necessary to shut the reactor down.

For the design certification, both the process that developed the minimum inventory and the actual minimum inventory list have been submitted by a DC applicant.

Based on experience, lessons learned that the staff has had with design certification reviews since the SECY letter was issued, the staff has determined that a more comprehensive minimum inventory can be developed, when more design details are available at the COL stage than at the design certification stage.

So for example, having a completed task analysis and human system interfaces will allow for developing a minimum inventory that is more representative of a complete and plant-specific minimum inventory of alarms, controls and displays.

So responding to staff guidance, that is to say, we have had an interim staff guidance document, and a more recent Branch Technical Position 18-1 on minimum inventory, what AREVA did was to provide a detailed implementation plan level description of the methods to develop the minimum inventory as part of its FSAR.

The list, that is the minimum inventory itself, the alarms, controls and displays, again following staff guidance, is now an ITAAC item, which allows for a more complete and accurate list to be developed at a later date.

MEMBER STETKAR: So we've now gone from having that list in the design certification, to something that is not even in the COL, because it's ITAAC?

MR. BONGARRA: It is part of ITAAC. The list itself --

MEMBER STETKAR: That's based on staff guidance?

MR. BONGARRA: That's based on our experience with --

MEMBER STETKAR: It's based on experience that people don't want to provide the minimum list up front?

MR. BONGARRA: Well again, I think what we've tried to do is to look at the concept of minimum inventory in the context of its purpose, and the fact that the development of that list, we've seen it more in terms of it being integrated with the element of human system interface design. We believe following the process that we have adopted for the other elements of the human factors engineering program, having a detailed description of the process is for design certification purposes, and then following that up with inspections of that implementation of the process, is a more reasonable approach to take for addressing this concept of minimum inventory.

MEMBER STETKAR: You said this is based on interim. This is the first I've heard about some of this. I mean I've seen what other applicants have done. It's another example of having -- suppose the absolute perfect, complete minimum inventory contained 100 items in that list. You're saying that well, because 100 items cannot be identified until everything is absolutely finished, we don't need any information.

It's pretty useful to have the first 95 of those, because those -- for example, if I were to look at that, from an integrated system human performance perspective, it would give me a pretty decent idea about how much the designers and the human factors engineers had thought about this whole integrated process, because they've actually the effort to say well, it's not complete.

It's maybe only 95 percent complete, and we need to add some specific things. There might be some site-specific design features that are factored in, because they changed the design of the service water system or thereabouts. But now we're saying that because you cannot have 100 percent of absolutely everything, nothing is available up to the point of COL issuance, and nothing needs to be available because that's a staff determination.

MR. JUNGE: This Mike Junge again.

MEMBER STETKAR: That's troublesome.

MR. JUNGE: Human factors is a DAC item.

MEMBER STETKAR: I understand that.

MR. JUNGE: Until they complete their task analysis, we really don't know what items will end up being in minimum inventory. And they will be part of the COL, because it will be an ITAAC.

MEMBER STETKAR: But originally, the intent was to have at least the minimum inventory in the DCD.

MR. JUNGE: That was if you --

MEMBER STETKAR: In the DCD, not even in the COL.

MR. JUNGE: If you go to 92-053, that said that we would have the minimum inventory -- 92-053 is prior to 0711. So that is where the comment was made that we would have minimum inventory. It says while we were developing our process, we would ask for a minimum inventory. Since 0711 is complete, that's our process. Minimum inventory isn't required anymore.

So again, going through the task analysis will provide us the detail of that minimum inventory.

MEMBER STETKAR: Just BTP-18.1 has been issued pretty recently.

MR. BONGARRA: It was sent out for public comment, and I can certainly get you the specific date and reference to that.

MEMBER STETKAR: Derek just, if I can get it.

MR. BONGARRA: In, I believe it was November of 2009.

MEMBER STETKAR: Oh, okay. So it's not really --

MR. BONGARRA: So we have circulated it

and received comments back on the BTP, and just as an aside here, we're in the process of revising NUREG 0711, and in the process of revising 0711, we're going to be taking into consideration the position in the BTP and the comments that we've received from the public.

MEMBER STETKAR: I have to apologize, not knowing about the status of the Branch Technical Positions. Our Committee typically is, you know, finds out this information after the fact, unfortunately. Okay, thank you.

MR. BONGARRA: Again, if it's necessary, I will provide that to you.

MEMBER STETKAR: That's fine. Derek's made some notes. I'd like to get a copy of it.

MR. BONGARRA: Okay. Moving on then from minimum inventory to the next slide and the next noteworthy item, procedures and training. This is to discuss how the procedures and training elements have been addressed. Actually, this was covered, I think already to some degree.

Both procedures and training, as was mentioned by AREVA, are considered to be operational programs. Because they are operational programs, the COL and not the design certification applicant is responsible for the development and implementation. These two elements are not evaluated as part of Chapter 18 of the design certification application.

Although reviewing it is probably for specifically inspecting these programs is at the COL stage, the guidance and the regulatory acceptance criteria that will be used to do these reviews, these inspections, are contained in Chapter 13 of our standard review plan. Of course, when these are inspected subsequently, they'll be an inspection procedure that will also guide the verification of procedures in training at a later date.

The last item I wanted to discuss is computer based procedures. Although overall the procedures programs just mentioned is an operational program, the design of computer-based procedures if an applicant elects to use that as a platform, is reviewed as part of design certification.

Because successful application of computer-based procedures relies heavily on the adequacy of the human system interfaces, that is, how well the display configurations, the visual display units can provide essentially unambiguous information and instructions, the staff considers it necessary for the design certification applicant to describe the methodology to develop these computer-based procedures as part of their human system interface portion of the program.

AREVA has proposed to use computer-based procedures with a paper-based backup. Because using computer-based procedures with this type of a backup is now a generally-accepted approach, the staff centered its review on the question of how would AREVA used paper-based backup procedures if there was a loss of computer-based procedures.

Well AREVA indeed provided an acceptable explanation. For instance, they indicated that a paper-based procedure backup would contain the same information, and in the same format as the computer-based procedure system. The computer-based procedures system itself has features that alert the operators in the event of a computer-based procedures system failure. There are certain alerts, alarms. There's a heartbeat mechanism built into the presentation medium to alert the operator if there was a failure to that system. The status of all open procedures is continuously recorded.

Also let me just mention that the computer-based procedure system is also an ITAAC item. So there will be an inspection of this, the actual design of this system, which will help ensure that AREVA's proposed approach for automating procedures with paper backup will actually work.

MEMBER STETKAR: Do you also look at training programs, to see how frequently operators will be challenged to bounce back and forth between computer-based procedures and the paper-based procedures?

In other words, when scenarios are developed for operator training programs, that regularly operators are challenged to either use a mixture of computer-based and paper-based things, because there may be some faults in the computer systems? Is that part of the staff's auditing of the training program, aspects of this?

MR. BONGARRA: I think it's really part of the overall integrated systems verification validation process, where there will be the opportunity to identify and review how procedures themselves are actually used in a realistic situation. So yes, the answer is yes.

MEMBER STETKAR: Okay, okay.

MR. BONGARRA: Well, last slide. In conclusion, I'd just like to say that the staff's review of the FSAR, Chapter 18, Human Factors

Engineering for the AREVA U.S. EPR certification has again, no open items, as mentioned, and the staff has determined that the technical content describing the applicant's proposed human factors engineering program is acceptable. I thank the Committee very much for the opportunity.

CHAIRMAN POWERS: Any other questions on this issue?

(No response.)

CHAIRMAN POWERS: Then I think we are scheduled to take a break, and we will do so until five of.

(Whereupon, at 10:37 a.m., the above-entitled matter went off the record and resumed at 10:55 a.m.)

CHAIRMAN POWERS: Let's come back into session and talk about something that's not gambling. Having survived the contentious world of Human Factors, we'll go into an area that has no controversies, no uncertainties. It's all deterministic analysis, right?

DR. SLOAN: Well understood.

CHAIRMAN POWERS: And I'll call a strange person who used to show up here fairly regularly, but does not, recently has not appeared very often. I vaguely remember what her name was.

MEMBER BANERJEE: Avoiding you or avoiding us?

CHAIRMAN POWERS: No. In fact, she did not reserve a slot on my agenda.

DR. SLOAN: Okay, okay.

CHAIRMAN POWERS: She does not want to be associated with this topic.

MR. TESFAYE: I have covered it earlier --

CHAIRMAN POWERS: And you have done an adequate, and even admirable job covering portions of it, and the staff will back you up later today. But we will begin first with Dr. Sloan, who has some credentials in these areas.

DR. SLOAN: Some credentials, which I won't bother repeating again. Thank you Dr. Powers and other members of the Subcommittee. We're here today to go through so-called Chapter 15, Group 2. If you will recall, we had been here before talking about other piece parts of Chapter 15.

Today, we'll be talking about the results from Chapter 15 regarding small break loca, large break LOCA and then the associated issues of coolable geometry and long-term cooling issues.

I did want to mention that in addition to the formal Chapter 15 Group 2 presentation, time permitting, at the end of the formal slide presentation this afternoon, we'd like to take the opportunity to respond to other Chapter 15 questions we had received in previous meetings. So time permitting, Dr. Powers, we'll see how far we can make it, but we can talk about that when we conclude the formal material.

CHAIRMAN POWERS: We have no constraints between now and midnight.

DR. SLOAN: Okay. We should be able to get through it.

(Laughter.)

MEMBER STETKAR: No, he can't be. He needs one more of us to have a valid subcommittee meeting. I'll be here.

MEMBER BANERJEE: He's equal to two of us.

CHAIRMAN POWERS: Yes. No, I need one other besides myself.

DR. SLOAN: Just as background in the area of Chapter 15, we presented to the Subcommittee in September 2009, just to give an overview of the methods applied in Chapter 15.

We were back in February of this year to talk about the non-LOCA results in Chapter 15, as well as the small break LOCA methodologies, and then in March, we were here again to talk about LOCA methodologies. So having covered methodologies, our purpose here today is to stick to the presentation of the results provided in the FSAR for both small break LOCA and large break LOCA.

Next slide. In the next slide, which I don't intend to read, it goes over the five discrete acceptance criteria in 50.46 that apply to these events, that will be addressed by the presenters.

Here, I'll turn it over to Liliane. Liliane, if you could just review your credentials just briefly again?

MS. SCHOR: My name is Liliane Schor. I am the supervisor engineer of the EPR LOCA Group. I have a degree in Engineering, all engineering from Polytechnic Institute of Bucharest, Romania, and I have a Master's in Nuclear Engineering from University of Cincinnati.

My experience here in United States, I worked at Brookhaven National Laboratory before moving to Yankee Atomic in 1978, and where I still work with other different names. We got bought by Duke and then bought by Framatome, and for the past six years, I am working for, on the U.S. EPR LOCA analysis.

What I would present now is results of the small break LOCA analysis, brief a few words on the methodology, the key --

MEMBER BANERJEE: Which presentation? Excuse me. Did I get this?

MEMBER RYAN: It's in the middle of this one, a few pages in past this.

MEMBER BANERJEE: Oh.

MS. SCHOR: The key codes used for SBLOCA analysis of the RODEX2 code, which predicts fuel to cladding gap conductance, fuel temperature, fuel rod gap composition and internal pressure as a function of power and exposure, and RELAP5, which is a system thermal hydraulic response. It also shows peak cladding temperature for the hot rods.

What we would like to present now, before we go into detail on the presentation, we would like to respond previous ACRS questions relevant to SBLOCA. In particular, we have four questions. One talked about the steam generator modeling, CCFL in Rossendorf facility, LOBI SBLOCA test and the control depressurization. On the steam generator -- next slide.

On the steam generator, the question was if we should use multi-dimensional representation of the steam generator secondary. A little bit about what EPR steam generator is. It's basically a boiler with an axial economizer. A divider place separates the cold leg and hot leg sides of the tubes. You can see here down the divider plate. This is a divider plate in a schematic way.

You will in the next slide a little bit more in the tubes. The main feedwater is directed between the bundle wrapper and the double wrapper here, as you see here the blue thing. No.

MEMBER BANERJEE: The blue is the feedwater?

MS. SCHOR: Correct, and it mixes with a ten percent recirculated water, and the nodalization we use represents the actual configuration of the steam generator secondary. You do have multi-dimensional effects above the partition plate, because you would meet the cold and the hot leg water end.

But we expect good mixing at that location. I think there is nothing different occurring above the partition plate between the EPR steam generator and the regular steam generators, and I do not think that the two remodeling is necessary.

In addition, the main feedwater terminator scram for both the loop and no-loop analysis. In the loop case, after the main feedwater terminates because you have loop, and in the no loop case, main feedwater terminates because it's a no safety system, one, and second, we isolate the main feedwater at high containment pressure for psi gauge, and which would occur for almost all the small break earlier in the event. In the loop case, EFW is automatically initiated.

Next slide. The EFW injects in the feed ring. You may not see, but it's colored in yellow, to make -- it's here, and there is no difference between the -- go back to the other slide. There is no difference in the feed ring in the EPR steam generator from other steam generator at the operating plants.

There is an equal partition of EFW on the hot side and the cold side of the downcomer. The MSIV closes. Again, the MSIV closes on high containment pressure, and there is no practically lower circulation due to low efficiency on the separator at low close.

In the case with the no loop, EFW initiates on low, wide-range level, and because we don't reach these for almost all the break with the accept of the two inch, where it loops later on the event, and you also have no heat up for the two inch break, so the effect of -- the potential effect of multi-dimensional effects on top of the partition plate do not exist, because EFW will be not injected.

So you would have pretty much circulated water on both sides for the cold leg. The difference in temperature between the hot part and the cold part is no different from the regular steam generator at operating plants.

MEMBER BANERJEE: The problem is this, that clearly the loop seal clearing is a very important event, and the issue is how sensitive is that to various assumptions you make. In all these types of calculations, clearly when you make relatively small changes to things like nodalization or whatever, the loop seal clearing changes by a lot. It's essentially an ill-posed problem.

MS. SCHOR: Correct.

MEMBER BANERJEE: Okay. So the question is even though to a first proximation you can probably do this within sort of a 1(d) type model, even changing the nodalization of this 1(d) model is going to change your loop seal clearing. It has to, because that's life.

MS. SCHOR: We did analyze. We do have and we submitted to the Commission.

MEMBER BANERJEE: Right.

MR. WIDMAYER: We did double the axial nodes in the tubes, and we also did the radial sensitivity, in which we assume three regions of tubes, the long, the short, the medium, and we did many break spectrum for four inch to about eight inch. We didn't see a lot of change in loop seal clearing. But I agree with you, that loop seal clearing --

MEMBER BANERJEE: I'm surprised.

MR. WIDMAYER: We were too, but I think what happened is that we did two changes to the actual methodology, which I think it helped stabilize the loop seal clearing behavior. One of it is that we put more nodes in the hot leg, so we have a very short portion that is inclined, instead of having a longer portion, which was -- instead of being horizontal, was vertical. So we --

MEMBER BANERJEE: So let me just interrupt you, because you're saying that you did -- you've divided the tubes into three lengths?

MS. SCHOR: Correct.

MEMBER BANERJEE: And that didn't show you a significant effect?

MS. SCHOR: We did not see a significant effect on loop seal clearing.

MEMBER BANERJEE: And did you see a significant effect on PCT?

MS. SCHOR: We did show more of an effect on PCT when we changed the axial nodalization. But the difference was not like 200 or 300, was in the region that we could say we do not have to go to this more detailed nodalization.

MEMBER BANERJEE: The staff presumably sent that to you as an RAI, right?

MS. SCHOR: This was --

MEMBER BANERJEE: You gave a response to that?

MS. SCHOR: Correct, and we do --

MEMBER BANERJEE: Because it's not in your FSAR.

MR. SALM: Ten times 263.

MS. SCHOR: We have EMF ten to --

MR. SALM: It's the codes and methods topical report.

DR. SLOAN: Codes and methods topical report.

MS. SCHOR: Correct, ten to --

MR. SALM: 63.

MS. SCHOR: 63.

MEMBER BANERJEE: Will the staff be

commenting on this?

MR. SALM: This is Bob Salm with AREVA. It was actually in a separate technical report that we prepared to address comments form the staff on the small break LOCA methodology. So this is a separate technical report that goes into a whole variety of sensitivity studies, and specifically focusing on small break LOCA.

DR. SLOAN: And it was in response to staff RAIs.

MR. SALM: Correct.

MEMBER BANERJEE: Yes.

MR. SALM: Well, I don't know if they were formal RAIs at that point, or they were from meetings that we had with the NRC. But it was in direct response to comments from the NRC.

DR. SLOAN: Yes.

MEMBER BANERJEE: And the staff will address you found this acceptable or not?

MR. TESFAYE: Yes.

MEMBER BANERJEE: Were there some open items still o this?

MR. TESFAYE: I'm sorry. I just stepped away. I don't know what the specifics of the questions were.

MEMBER BANERJEE: Sensitivity.

MR. TESFAYE: Shanlai, could you please?

MEMBER BANERJEE: If you are going to talk about it later, that's fine.

MR. LU: Yes, we can talk later, and then actually specifically related to -- oh, let me identify myself. Shanlai Lu from staff. We'll talk later, I think in the afternoon, and then overall as the small break LOCA analysis, we still have open items remaining. So it's not conclusive yet, but AREVA's calculation is heading to the right direction overall. Then so I think you'll hear more of the details.

MEMBER BANERJEE: Yes, so let's move on. So you fact resolve it. If I understand it, instead of doing two, a few 3D, what you've done is you've done some radial assessments and some more normalization in the vertical direction, but not both. So you've done it separately.

MS. SCHOR: No, no, we did separate, and the report, the report is 310-291P.

MEMBER BANERJEE: Right. Maybe, Derek, we need to look at that.

MS. SCHOR: The second question that you had was related to the German test in the Rossendorf facility, and as how it would compare to what we use, and what we use in our small break LOCA model, of the connection between the hot leg and the steam generator plenum, we use a correlation based on Wallis CCFL, and we assess it against separate effect test, UPTF Test 11, and we used it in overall tests in ROSA-IV five percent breaks, semiscale S-UT-08, and BETHSY 9.1(b), a .05 percent break.

What we did was a TOPFLOW CCFL data. We used the valid paper and we compare the data to our correlation. As you can see, we are conservative, as compared to the steam waters test, and we are not as conservative with the air water test. But we had similar tests in the, I mean there's a 1.5 bars. Three bar is UPTF facility, and in that facility, we are quite conservative. We usually have a correlation.

MEMBER BANERJEE: Yes. It could be -- they sort of think it's a viscosity effect, which I don't think is correct. But maybe it's something else.

MS. SCHOR: What they had shown in the paper is that when they adjust the Wallis correlation with the viscosity effect, the two, the air water and the steam water go on one line. We did compare, we did use our correlation. We adjusted for viscosity and we compared to their newfound correlation, and we still found that are conservative using our correlation.

MEMBER BANERJEE: Let me, remind me. What is your hot leg area to core power, compared to existing EWRs?

MS. SCHOR: We have that. I have it. I will get back to you at lunch. I have it written.

MEMBER BANERJEE: Yes. I'm sure you do.

MS. SCHOR: That's it, I do. We have the U.S. EPR, the cold leg area versus power, but the area of cold leg-hot leg similar. We have 0.112 percent area of power for the U.S. EPR. On a typical four loop, it's 0.119 percent, and in a three loop, it's 0.142 percent, but as we compare with a typical four loop.

Actually, in my mind, EPR is like a bigger Seabrook. That's my opinion. So it's --

MEMBER BANERJEE: You're in the range of --

MS. SCHOR: Correct, to other plants of the same --

MEMBER BANERJEE: Except you don't have a high pressure injection system.

MS. SCHOR: No, but I don't think that precludes getting good results, because you have low power density for this one.

MEMBER BANERJEE: So in broad terms, I'm sure you will visit this, compared to a normal PWR, do you get into refluxing earlier at a higher power?

MS. SCHOR: Yes. We have -- I did plot the velocities and adjust the disconnection, and liquid and the liquid flow and the vapor flow for -- I took four inches and the six and a half inches are limiting, and you can see that first of all, you have a short period of refluxing. It's maybe for the four inches, stopped at about 200 seconds and it goes maybe up to the time accumulator inject and the loop seal clear, maybe about 200 seconds.

MEMBER BANERJEE: Right, right.

MS. SCHOR: And for the six inch, it starts a little bit after the pump closed down, maybe 50, 60 seconds, and it goes about the same amount of time. So it's not -- but you do see a clear liquid reversal of the --

MEMBER BANERJEE: So the floor is below the JL and it's below the flooding?

MS. SCHOR: Correct.

MEMBER BANERJEE: And this is at higher

power than you would expect it in a normal four loop PWR, right?

MS. SCHOR: I don't know what.

MEMBER BANERJEE: Well, we'd have to look at that. But nonetheless, the main thing is you're below the flooding limit, which was my concern.

MS. SCHOR: Yes. What happened is that we put a high K reverse at the inlet to the hot assembly. So we preclude quench from the top in the hot assembly. So even so, you may have reflux from the top earlier. That would not affect the PCT.

There is some secondary effect, because you do have water penetrating into the average core, and you have cross-flow between the average core and the hot assembly. But that has -- it's a secondary effect to reflooding from the top.

MEMBER BANERJEE: And you have a period of core uncovery, right?

MS. SCHOR: Quite, yes, and you would see, we do have core uncovery for all breaks, starting at two and a half inch, to the ten percent break, which is the max break that we are allowed by SCR to analyze.

MEMBER BANERJEE: Okay. We'll come to that, then. But thank you for doing this comparison.

I'm surprised that you hadn't used this data before.

MS. SCHOR: We --

MEMBER BANERJEE: So your German colleagues are not using this data, even though it was generated in Rossendorf?

MS. SCHOR: Mr. Nithian had a talk with them.

MR. NITHIANANDAN: Yes. My name's Nithian and I work for the LOCA Group, and yes, German colleagues, and we were trying to make contact with the group who run the test, and we're trying to see whether we can -- because of the nature of the data I think was done for the GRS.

So we're trying to see whether we have -- previously, we had got some other UPTF data. So we are trying to see whether we can get the data from them, but not got it yet.

MEMBER BANERJEE: The person who sort of oversees this experimental facility is Uwe Hampel. Weiss, who was in charge of the division, is moving to GRS now. But he's becoming boss of GRS. But I think Uwe is still in charge of this.

MR. NITHIANANDAN: I think the person we were trying to contact was one of the owner in the --

MEMBER BANERJEE: Balet (ph).

MR. NITHIANANDAN: Yes, I think that's him.

MEMBER BANERJEE: He's graduated. This was his Ph.D. thesis. I think he's gone.

MR. NITHIANANDAN: Oh, okay.

MEMBER BANERJEE: So he didn't reply because he's not there.

MR. NITHIANANDAN: No, because I tried to contact him through our colleagues in Germany. That's what --

MEMBER BANERJEE: The guy you should contact with Hamper. You should definitely put this stuff in your database.

MR. NITHIANANDAN: Yes.

DR. SLOAN: Thanks.

MS. SCHOR: The next question you had was about the LOBI, as we --, and Germany LOBI tasks are natural situations. There's multi-clocker tests. I looked at two. One is international sample problem 18, and it's -- both are one question. They just, the paper presents it in terms of simulator one and one percent counter clock.

Now the first test, ISP-18, has a four situation phase and control depressurization is a steam generator --, 100 degree K per hour, and it's pretty much a regular small break LOCA. It has a four circulation phase where the pumps are running. Then the pumps are tripped and close down, and HPSI injects, and after close down, you have a two phase natural circulation, following by voiding and the reflux condensation in the steam generator.

What was important for this test was distribution of inventory in the primary loop, and there was no uncovery, and so it was hard to determine the effect of reflux condensation, other than inventory distribution. The other test I looked at was a LOBI BL-06 test, which is part of the CAMP group members that they did this test.

This was a very interesting test, and because it has a long period of -- pumps run quite a long time, up to about close to 3,000 seconds, and you do have pump degradation because of the two-phase flow, and you have asymmetric degradation between the broken loop and the intact loop.

You have CCFL just in the impact loop at the inlet to the steam generator, and when the pumps stop to end of accumulated injection, you have reflux cooling and quench from the top.

Then accumulator finish injection, and you have a second heat-up, until LHSIs stopped pump injecting, and then there is enough flow that the second quench, the second heat-up stops fairly soon after LHSI injects.

MEMBER BANERJEE: What was the pressure at which the accumulator stopped injections, 600 or --

MS. SCHOR: Oh, I have the paper. It starts at about, I'd say 85. The pressure is about three megapascal.

MEMBER BANERJEE: I have to convert that, okay. That's about 400 psi, yes. Okay.

MS. SCHOR: And we, I looked at this test, and I decided it is interesting from the point of view of reflux cooling, because it has a long period of reflux cooling. But we have the same long period of reflux cooling in BETHSY 91(b). We didn't assess those tests with our methods, but they were assessed by CAMP members with both RELAP5 Mod 2 and RELAP5 Mod 3, and they show acceptable results, both these tests.

There is that effect of user effect that people are talking about, but we do use pretty much the same codes and the same inputs that come from NRC database, and we expect had we analyzed them, would have expected similar results to whatever the community had obtained.

MEMBER BANERJEE: Were there any tests

done where they did a control cool-down of the secondary side?

MS. SCHOR: We did, and you will see -- next slide. That was your last question.

MEMBER BANERJEE: Right.

MS. SCHOR: What we had is a BETHSY test 9.1(b). We had, it's 0.5 percent in the pressurizer. This is a test we performed and it has three different phases. The sub-cooled blow down, the mass depletion in primary site, and then when the temperature in the core reaches about 715 degree K, they start what they called ultimate procedure, which they open the damp valves in the secondary side to depressurize the primary, and it starts at about 2,500 seconds, and ends with the accumulator isolation at about 3,800 seconds.

So it has a long period in which you depressurize the primary with the secondary, and you do have condensation in the tubes, and you have liquid fallback in the core, and you could see the core being quenched from the top, and then accumulator injects and you have a bottom up reflood.

Then after accumulator, accumulator isolates, you have a period of no ECCS injection, and there was no heat-up. So the primary pressure drops to LHSI actuation at about 51, approximately 5,100 seconds, and LHSI flow becomes larger than the bridge flow and recovers the core.

We do it, we did use these tests to -- it's part of our benchmark for small break LOCA, and in addition to that, we also do a scale, a scaling analysis of these tests, and we found the scale reasonable to U.S. EPR.

MEMBER BANERJEE: The only problem with the scaling I would say is the diameter of the core, compared to -- because your refluxing will tend to run along the sides. So you can't really scale the temperature traces very well here.

You can scale the fluid dynamics probably, but not the heat-up of the core. It's just that the core is so much larger and the three dimensional effects will become very important, because the refluxing comes along the sides, sort of run down the outer channels.

MS. SCHOR: What we didn't really scale the temperature. We only scaled the thermal hydraulic phases.

MEMBER BANERJEE: Yes.

MS. SCHOR: Flow down the two phase circulation loops in clearing, and we did look at heat up and reflood of the core, but again, from the thermal hydraulic point of view.

MEMBER BANERJEE: That's when water is coming in and --

MS. SCHOR: Correct, and terms of timing and non-dimensional parameters of interest. This is all what I had to say about the questions you have asked at the last presentation.

MEMBER BANERJEE: I think you've answered them.

MS. SCHOR: Thank you. Now we go back to U.S. EPR, a few unique features of the SBLOCA that were presented before. I felt that they are helpful in the SBLOCA analysis. We do have four trains of accumulators, four trains of ECC.

We have four accumulators, four LHSI pumps, four LHSI EFW and four MSRTs. As LHSI are cross-connected, and the valve as the cross-connect opens, when one train of LHSI is removed for preventive maintenance.

We have automatic partial cool-down of the steam generator on SI signal. That helps to cool down the primary, so the MSRT, so the LHSI can inject. EPR has an automatic trip of reactor coolant pumps on coincident SI actuation and low DP across the pumps.

It has in containment refueling water storage tank, which is a source for ECCS water, and you do not need to make the switch from RWST tank to the pool-like for operating plants.

MEMBER BANERJEE: If you don't have loop, roughly when does your pumps knock out? Because you're going to get more flow-out, right?

MS. SCHOR: The pumps --

MEMBER BANERJEE: The worse condition is without loop, right?

MS. SCHOR: If the worse condition is without loop, and that is not a difference between the PCT --

MEMBER BANERJEE: But the pumps keep pumping.

MS. SCHOR: The pumps, we found that -- we looked at all the breaks.

MEMBER BANERJEE: You break it downstream of the pump, right? That's probably your worst break.

MS. SCHOR: Correct. We found that the pumps trip at the void fraction of 0.17.

MEMBER BANERJEE: How did you arrive at that, experiments?

MS. SCHOR: We used algebraics and we saw that all of them pretty much trip at the same --

MEMBER BANERJEE: You have the same model, right?

MS. SCHOR: But we have, we looked at the DP and we had a question, actually. If the pumps were tripped for a steam generator to rupture, as compared to a small break LOCA, and they don't. Which is good, because you would have mixing in the primary system if the pumps are running for a steam generator.

MEMBER BANERJEE: But I'm quite interested in this, because if the pumps are running, you tend to get more stuff out of the break. So you lose your inventory faster.

MS. SCHOR: Correct.

MEMBER BANERJEE: But you don't lose the energy, because if the break is at the bottom, you get water out, and you don't get steam out.

MS. SCHOR: We see that, but what happens is that because of the DP, the DP is 80 percent with the degradation five percent and 75 percent from nominal. So the pumps are tripped not so -- I mean there is a close down and everything. Not so much from the loop case, and I do have, if you are interested for, pretty much for every break I have charted the RPM for the loop and no-loop.

The difference is not much, maybe one when the finish comes down at 50 seconds. Like for example, for six and a half and for the no-loop case at close down, we're talking about 110 seconds. So the amount of inventory lost during this time is not as much, to make a big difference in PCT between one case and another.

MEMBER BANERJEE: But partly that's due to the model you're using for your break flow. You are using, of course, the Moody.

MS. SCHOR: Yes.

MEMBER BANERJEE: But you're probably -- the problem with that model is it doesn't tell you -- if you're using the evaluation models, then it's fine. You have to do it that way. But it's not very good, because clearly you get more liquid out. It depends on the break orientation, and the Moody model as you use it does not show any effect of --

MS. SCHOR: Of orientation, because there's some equal velocity.

MEMBER BANERJEE: Right equal velocities. So you don't get more liquid out. So in reality, it's an artifact of the model you're -- of course, you're using it as you're required to, because that's your evaluation model, right?

MS. SCHOR: I think that the how long are the pumps running. For example, the Westinghouse model. They run it long. So there is a period in which indeed, if you trip the pumps at that point, you will exceed 2,200 at the core of that cover, and it goes asymptotic during that period.

But even there your combustion, when they use best estimate models to do the same thing, they didn't see that behavior. In our case, indeed we are using Moody. I don't know if it will make much of a difference if we use HEM or --

MEMBER BANERJEE: Probably not. You're using equal velocities, right?

MS. SCHOR: On HEM, correct.

MEMBER BANERJEE: On Moody, you're using equal velocities?

MS. SCHOR: Equal velocity, yes, and but I think also the fact that they trip early make a difference too, and we saw that for the operating plants, that when the trip occurred early, there was not much of a difference in PCT when they did post-DRI analysis.

Now I agree, and we see that, that we have more break flow when the pumps are running, even with Moody. But not enough to make a big difference in PCT.

MEMBER BANERJEE: Part of it is due to the equal velocity assumption. If you made a different assumption, and you got -- let's say I had a break which took more liquid out than the steam, then I think you will see some more difference. But I don't think it will be very much. I don't know. I have to think about.

MS. SCHOR: Okay.

MEMBER BANERJEE: At the moment, you're using -- and then you're using a sub-cooled discharge model which is different from Moody, right?

MS. SCHOR: During the sub-cooled, we use Ransom TAP, whatever a five model has.

MEMBER BANERJEE: So then there will be some significant discontinuances in that model, right?

MS. SCHOR: No, because there is --

MEMBER BANERJEE: Will that smooth it over?

MS. SCHOR: There is a smoothover with Almagir whatever.

MEMBER BANERJEE: Almagir-Lienhard.

MS. SCHOR: Yes, but it smooths over.

MEMBER BANERJEE: All sorts of tricks and --.

MS. SCHOR: I mean it's better to smooth

it than to have a jump. So but there is, when you switch to Moody and we had a question for the NRC, we do have --

MEMBER BANERJEE: Discontinuation.

MS. SCHOR: Discontinuation, even with the smoothing.

MEMBER BANERJEE: All right. Well, these are all artifacts of the EM, the model you are using.

MS. SCHOR: I mean we have to use it, unless we move to --

MEMBER BANERJEE: Yes, but you're not doing that for SBLOCA.

MS. SCHOR: No, we don't for a small break. Next slide. Ahh, the other feature, which I think it helps, it's a shallow contact cross-over typing. Travel route seal, it's a certain millimeter below the top of active core. So that helps in the loops in clearing, so you don't have as deep --

MEMBER BANERJEE: Do you have a diagram of this somewhere, because I know this feature, but it would be nice to see what it looks like physically.

DR. SLOAN: We kind of did it before.

MEMBER BANERJEE: Yes, maybe you did. But I've forgotten, yes.

DR. SLOAN: In one of those previous

slides --

(Simultaneous speaking.)

MEMBER BANERJEE: That would be useful, because it's quite an interesting feature, and it helps you with your boron as well, right?

MS. SCHOR: Correct.

MEMBER BANERJEE: Yes.

MS. SCHOR: But again, we have --

MEMBER BANERJEE: Okay. So you can show it later.

MS. SCHOR: As the model, again we presented that before. We have two-dimensional modeling in the downcomer and core. The core is divided into three regions, the hot assembly, an inner region comprised of 30 percent of the assemblies, and an outer region, which is the rest. We have four heat structure, hot rod, hot assembly, an inner and an outer or low power core region.

The two loops are biased downward. The broken loop and the intact loop closes to the break. They are biased downward by one foot, to ensure a conservative clearing, and we assume conservative scram characteristics, but that's also an EM feature, with a maximum time delay.

Next slide. Those are some selected

initial condition. We assume thermal power, which it's .084 percent higher.

MEMBER BANERJEE: .085 percent higher, .85 percent?

MS. SCHOR: Yes, because it's a Caldon, we use a Caldon.

MEMBER BANERJEE: Don't tell me; I'll have a heart attack on this.

MS. SCHOR: I mean that's what -- I mean this is something that --

MEMBER BANERJEE: I know. We've had many discussions on this.

DR. SLOAN: And we have a prepared statement to address the question you had had at a previous meeting regarding power measurement uncertainty. So in the afternoon session, we'll talk about that. We've gotten some information from the vendor.

MEMBER BANERJEE: Oh my God. Is it a sales pitch?

DR. SLOAN: No.

MR. SALM: This is Bob Salm from AREVA again. I think there's a typo up there. It's half a percent.

MEMBER BANERJEE: Yes. It sounds

incredible.

(Laughter.)

MEMBER BANERJEE: Thank you. I was --

MS. SCHOR: Then we used Fq and FDH tech spec limit. We have the most top-skewed power shape, over eight possible cycles, the 18 month cycle and 24 month cycle, including for 18 and 24, the equilibrium cycle, and we picked up the ULC top-skewed of all this.

The coolant flow is a tech spec minimum, with a bias for uncertainty, and we assume five percent clogging. So the secondary system pressures, feedwater flows, inflow, corresponds to the five percent clogging in the generator. The operating pressure, pressurizer level is average temperature nominal. So LHSI, the ECCS and BMW temperature are, assume the maximum tech spec temperature for IRWST.

The pressure, we assume minimum pressure in the accumulator, 653 psi, and we assume a nominal temperature of 90 degrees for the accumulators.

MEMBER BANERJEE: What is the maximum pressure for the accumulator? Can you give us a range? Just the physical --

MS. SCHOR: Because I'm not very quick on this. 17.7.

MEMBER BANERJEE: Okay, thanks.

MS. SCHOR: For large breaker samples.

MEMBER BANERJEE: Correct.

MS. SCHOR: The analysis was performed from three inch break to a ten percent of the core length area. We use Appendix K, Deterministic Methodology. The key parameters, protection system set points in ECCS performance are biased for uncertainty, in accordance to Reg Guide 1.105.

The other inputs which have minimal bearing on the results are nominal. We do not credit non-safety related system if they help you and we do assume that they operate and they are detrimental to the analysis. We isolate the accumulator as soon as non-condensable gases are detected in the nozzle in the analysis.

The reason we did that was because when you start injecting non-condensable switches to HEM, and we felt that that would not be in compliance with Appendix K, and we responded to questions as to what happened when accumulator it's left to inject. We assumed that --

MEMBER BANERJEE: Your analysis stops at that point, or what happens?

MS. SCHOR: No. We isolate the

accumulator and we continue --

MEMBER BANERJEE: But in reality, of course, you'll get --

MS. SCHOR: In reality, you would get nitrogen to inject. If now again, we did not do yet the detailed design analysis. It's, for example, for the BMW? plant. It's isolated so nitrogen does not inject into the system per EOPs. So we do not know yet what will are these EOPs for the U.S. EPR. So it is possible that --

MEMBER BANERJEE: What is it in Europe or Finland or wherever?

MS. SCHOR: I don't think that they are isolated. I think they are allowed to inject.

MEMBER BANERJEE: And when you do that, if they're allowed to inject, this is another discussion we've been having, adiabatic, isothermal partially in between whatever, because if it's adiabatic, clearly it becomes very cold at some point.

MS. SCHOR: That is beyond the time --

MEMBER BANERJEE: That's you're interested in.

MS. SCHOR: That I am interested in, correct.

MEMBER BANERJEE: But it has implications on things like stresses.

MS. SCHOR: Yes, but again, it's beyond the type of analysis that I am concerned with.

(Simultaneous speaking.)

MEMBER BANERJEE: All right. So that's what you assume.

MS. SCHOR: That's what I assume, and we deal --

MEMBER BANERJEE: And somehow you deal with it like if it was not isolated. If it's isolated, it's fine. But if it was not, then your analysis becomes more qualitative after that, right?

MS. SCHOR: We did have to respond to some NRC questions related to what's happened if nitrogen would inject, and we did analyze a few of the cases, assuming nitrogen injects, and we show for the cases that we analyzed, which is the time frame of these analyses, that the break flow was large enough that nitrogen was entrained around the annulus and out the break.

It did not accumulate in the upper portions of the system to impede heat transfer in the generators. As part of the detailed design, we are planning and we started to do more condensable, what will happen if the hydrogen from the solution, the nitrogen dissolved in the accumulator water, and there are a few non-condensable sources.

We looked at all of them, and we looked at how much would be in the primary system and we assumed that they will be in the entire primary system or just in the generator. But this is something that we start to do and we plan to complete, as part of the detailed design.

MEMBER BANERJEE: So your argument for the fact that it won't block your steam generators is that you have sufficient flow to entrain them and --

MS. SCHOR: And go out --

MEMBER BANERJEE: Out of the break.

MS. SCHOR: Out the break for the nitrogen --

MEMBER BANERJEE: Is that an open item, or is it still being --

MS. SCHOR: No, I don't think it's open.

MEMBER BANERJEE: You've made a sufficient argument?

MS. SCHOR: Correct.

MEMBER BANERJEE: Okay. We'll hear from the staff, I'm sure, on that.

MS. SCHOR: What we had, the analysis assumption, we assume there was single failure, that we lose one train of ECCS and EFW. We assume one train of pump ECCS injection and EFW is unavailable, because it's preventive maintenance. We assume that the start-up time for pump ECCS and EFW. We assume loop, so you have the added time to start the diesel generators.

We assume that two operating ECCS trains deliver water to the break and to the loop adjacent to the break. So it has a possibility, if there is bypass, that will be the closest. The most bypass flow will occur in the loop close to the break.

MEMBER BANERJEE: What do you assume about the core bypass?

MS. SCHOR: I assume 5.5 percent core bypass, which is a maximum bypass calculated for the plant. I have every, it's in the -- the bypass is divided between the control room guide tube bypass and the heavy reflector bypass. I do not have a hot leg downcomer to hot leg bypass. We assume that that is -- that it doesn't exist because that is benefit for small break LOCA, and there is an uncertainty on that particular opening, varying from zero percent to 1.03 percent.

We add, we assume the maximum bypass, but we add that bypass to control room guide tube, and we assume bypass between the downcomer and the upper head. The maximum bypass here varies -- I mean the bypass varies between 0.33 percent to 0.39 percent. We assume 0.33 and the rest of 0.06 percent we add it also the control guide tube.

MEMBER BANERJEE: Is this worse than knocking out an accumulator?

MS. SCHOR: I did that. I did do three single failures. I assumed that. I assume that we lose one MSRT, and I assume one accumulator failed to eject, and this is the worst single failure. For the EPR, accumulators are passive, and so are single failure proof. But I did it anyway.

MEMBER BANERJEE: And it still didn't give you worst case?

MS. SCHOR: Correct, and we do have that documented. Next slide. We have the protection system. We treat the reactor on low pressurizer of low hot leg pressure. We assume that the signal is biased for harsh containment. The condition of 55 psi of certainty of low pressurized hot pressure, and 75 percent of certainty for hot leg pressure.

We assume main feedwater isolation is continuous for loop. The EFW, as I said before, injects loop and SI, and falls no loop case injection wide range level, and that is also biased for harsh condition, quite high uncertainty.

The main steam relief train, we assume nominal and normal uncertainty, because the signal, it's outside containment. So certainty SI, and reactor coolant pump trip and SI injection signal on low pressurized of pressure, again they are most biased for harsh conditions. Five percent for the coolant pump trip, and 55 psi is the same as a trip in the pressurizer. That -- the main protection system supports.

This is the results of the small break spectrum closed loop. The PCT, 1638 for a 6.5 inch break. We did, in addition to the normal break spectrum, we also did an ECCS line break. For the no loop case --

MEMBER BANERJEE: Because you see that there is no trend, right, in the previous --

MS. SCHOR: There is not as much --

MEMBER BANERJEE: Trend as you would hope.

MS. SCHOR: I mean we have a figure, and we were asked this question by the staff, and there should be a trend.

MEMBER BANERJEE: All due to the seal clearing, I imagine, in all that's random. Not random, but --

MS. SCHOR: Actually, it's not exactly random. We do have one loop seemed clear up to 3.5 inch. We have two loop seemed clearing after about seven inch, and then three for 7.5, and then four for the rest. So I think what we have, you know, they do go like that. I note that you will set this plot.

MEMBER BANERJEE: Okay.

MS. SCHOR: It's more like the hot leg draining, and loop seal timing, and it's not only the loop seal, the first loop seal that clears. The second and third loop that -- the other loop that clears, the timing of the other loop also have an effect on PCT. Like if they clear 50 seconds early or 100 seconds later, it has an effect on PCT.

There is a mistaken belief that it should be monotonic. It should go up to the peak and go down, and it should look like that. I looked at the Westinghouse -- I looked at the EG&G analysis of the -- Westinghouse confirmatory analysis, with some RELAP5 type analysis.

I also looked at CATHARE break spectrum for U.S. EPR. We have similar results, and we did have the question from NRC of why it looked like that, and we responded by showing that the same behavior occurs for --

MEMBER BANERJEE: But if you change the nodalization, this will also change a little bit, because it's very sensitive to --

MS. SCHOR: How many nodes you have in the hot leg, in the cold leg.

MEMBER BANERJEE: All that stuff, yes. But it's the general results. I mean you've got a good margin to --

MS. SCHOR: Correct.

MEMBER BANERJEE: That's really what matters.

MS. SCHOR: We do have pretty much close to 600 degree margin. So you cannot change so much.

MEMBER BANERJEE: Right.

MS. SCHOR: Next slide. We did a no loop pump trip sensitivity. We changed the transient deck to change the delay on ECCS actuation and EFW actuation, such that EDG delay was not taken into account. We assumed that separate, different than what we did on the loop case, that the close down, we closed down almost the time of main feedwater closure.

We do have the low load main feedwater, but we neglected, because it's a non-safety system. The main steam bypass was not used. Again, it isolates on high containment pressure, and we also use like for the loop case, the MSRT system for steam generator depressurization. The pumps were tripped on 75 percent DP across the pumps, and EFW was actuated on low wide range level.

These are comparison between the case with loop and non-loop. The PCT for the six and a half inch break with loop, it still, it was a limiting case, and we do have more of a monotonic behavior for the case with no loop.

Now here, I have the main events for -- and I have a table, and I also have -- I won't get to the other ones. We have the main event, I also presented in the system pressure figure, and we do -- no, previous, previous. We do have scram on hot leg pressure at about four seconds. I think we should move between one and another.

We do have the SI signal occurs at about 14 seconds. The MSRT starts at about 140 seconds. We have the opening of the isolation signal. Because the MSRT -- the MSRT is made of two valves, an isolation valve and a control valve.

The control valve, it's normally opened. The isolation valve is normally closed. But as we scram, the control valve closes from 100 percent open to 40 percent open. So when the isolation valve opens, you have a higher flow, and then the control valve closes, in order to preserve the control depressurization. It reopens at about -- it reopens at about 170 seconds.

The emergency feedwater starts to inject at about 76 seconds after SI signal, because of the EG&G and the pump start, and the loop seal clear at about 234 Loop 2, and 237 Loop 3. Those are the non-bias loops, and soon after loop seal clearing, MHSI starts to deliver its flow to Loops 4 and 1. Loop 4 is a broken loop, and Loop 1 is the one adjacent to the break.

The break uncovers at about 250 seconds, and the accumulator starts injecting at about 340 seconds. We do have Loop 1 and 4 starts to clear at 360. They both kind of clear at about the same time, 360 seconds, and LHSI injects too.

(Off mic comments.)

MEMBER BANERJEE: When does the accumulator empty?

MS. SCHOR: Accumulator does not empty for a 6.5 inch break.

MEMBER BANERJEE: Okay.

MS. SCHOR: In the period that we have

this case.

MEMBER BANERJEE: Up to 1,000 seconds?

MS. SCHOR: Correct. The LHSI starts injecting at about 340, 360 seconds. I don't -- and we ran the transient up to 1,000 seconds, to show that there's a consistent cooling and level, and as the vessel starts to increase, ECCS injecting exceeds the break flow.

I have two figures. One is the collapsed level. One figure here we have the steam generator secondary and the primary pressure. The next is collapsed level is the hot assembly.

As you can see, we uncover the entire core, and we do have some recovery at the time of the loop seal clearing, but not enough to quench the core, and we do quench at the time of the accumulator injection, and the time of the other two loops here are clearing.

Next slide. As you could see, we do -- the behavior is more like a large break behavior, in the sense that we don't have two heat-ups with the loop seal clearing, and then followed by quenching to close to saturation, and then another boil off heat-up.

We don't have, we hardly have any recovery at the time of loop seal clearing, and the quench occurs at the accumulator actuation, and the time of the other two loop seals clearing. The results --

MEMBER BANERJEE: To some extent, it doesn't even matter if you flood during the refluxing phase, because you're not taking any credit, more or less none for refluxing at all.

MS. SCHOR: In the hot --

MEMBER BANERJEE: Yes.

MS. SCHOR: I do think that it takes, it does something, because we do allow flow to the average core. It's a peripheral is some --

CHAIRMAN POWERS: Cross-flow.

MS. SCHOR: Some cross-flow. Now the PCT for this break is 1638 or below the limit-specified intensity of 50.46. Cladding oxidation is 17 percent, and hydrogen generator is below one percent. So we meet the three, the first three criteria of 10 C.F.R. 50.46. My other colleagues will present large break and long-term cooling.

MEMBER BANERJEE: And the boron will be considered under long term?

MS. SCHOR: Correct.

MEMBER BANERJEE: Yes. We have a long day ahead, I hope. No.

CHAIRMAN POWERS: An easy day.

MEMBER BANERJEE: All right.

CHAIRMAN POWERS: We've got to do Human Factors, so this might be easy.

MEMBER BANERJEE: Right. I think you addressed my questions very well, so I'm happy.

CHAIRMAN POWERS: Any other questions you'd like to pose? I think I will break for lunch at this point, until a quarter after one, and then we'll reassemble for large break LOCA analysis.

MEMBER STETKAR: That sounds good.

MEMBER BANERJEE: The famous non-parametric.

(Whereupon, the above-entitled matter went off the record at 12:15 p.m.)

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

1:17 p.m.

CHAIRMAN POWERS: Let's come back into session, and we're going to discuss the large break LOCA, and associated issues of boron, right?

DR. SLOAN: Yes.

CHAIRMAN POWERS: I am dying to hear about boron absorption.

DR. SLOAN: Okay. We'll start with LOCA.

MR. ABEL: Okay. Good afternoon. My name is Ken Abel. I'll give you a little bit of background about myself. I have a Master's of Science and a Ph.D. from Oregon State University in Nuclear Engineering. I did a short, I did a postdoc over at, for IRSN at the Cadarache facility, and for the past five years, I have worked on EPR doing both LOCA and on LOCA calculations.

So to get started, we'll be going over the large break LOCA results. First, I'm going to talk about some of the important design features for U.S. EPR that are important for large break LOCA. So the first is the passive containment heat seats for containment heat removal.

The second is the IRWST. This is the source for the ECC water. We have medium head safety injection as to opposed high head safety injection found in several operating plants. The accumulator pressure tends to be a bit higher for EPR at approximately 700 psia, and our LHSI cross-connects, which are opened when one LHSI train is removed for preventive maintenance.

So the key features for the realistic large break LOCA methodology is the probabilistic methodology, and we perform two sets of cases, 124 cases each. We looked at the initial fuel cycle and then an equilibrium fuel cycle representative of an 18 month core.

On this slide, we show some of the same parameters and what the typical ranges are. For instance, for core power, we're using 100 percent plus uncertainty, and that's just the fixed value, it's not sampled. As another example, accumulator pressure will range from say 752 to about 710 psia.

CHAIRMAN POWERS: So how do you -- I mean you showed an upper bound and a lower bound.

MR. ABEL: Yes.

CHAIRMAN POWERS: I mean what fixes -- is there some --

MR. ABEL: Those are typically tech specs, tech spec limits for a max and a min. I think that's the case for all of these listed. Some of those are related. For instance, pressurizer level, that's the uncertainty, you know. The nominal would be 54.3, plus or minus five percent.

CHAIRMAN POWERS: Okay.

MR. ABEL: Do you have something?

MEMBER BANERJEE: I must -- sorry I came back late, but I must confess to being totally befuddled by this non-parametric statistics. I'm actually writing a paper on it, just to learn about it. But which is probably the best way. Is this, the fact that you're doing this, are you sampling the break size here as well?

MR. ABEL: Yes, that's correct.

MEMBER BANERJEE: As one of the parameters, and then you've got three output or two output parameters, right, temperature, amount of oxidation?

MR. ABEL: PCT, local oxidation core-wide.

MEMBER BANERJEE: Yes. Now the way I was reading Wilkes and Wallis' papers, and you can -- is that when you have that going on, you need more than the 59 or a 124 or whatever the number is. What's your -- is this sort of a licensed methodology? What state are we at? I mean I know that Westinghouse, for example, has licensed ASTRUM or whatever, which has a certain set of limitations, and whether we agree or not, it's licensed.

Is this now something which has been, gone through sort of a licensing process, or let's say accepted or approved? It's not licensing, but is it an accepted or approved --

DR. SLOAN: It's really a two-part answer, Dr. Banerjee. One part is AREVA had a methodology approved with 59 cases. That is, I'll say, our existing methodology for certain plants --

MEMBER BANERJEE: With a certain break size. Is that just one break size or --

DR. SLOAN: No. I think it's the same fundamental methodology we've seen here. In the process of reviewing that methodology for application to EPR, we got some very specific questions from the staff, and have adapted our approach. They identified, their concern was 59 cases might not be sufficient.

We did our homework, looking at different numerical methods, all our experts looking at it, and we came to a point. I think the staff has, in their SER, accepted 124 cases, with the sampling of the parameters that Ken has been talking about.

MEMBER BANERJEE: Okay. So you haven't got a separate topical or anything?

DR. SLOAN: There is a separate topical for this, and without being too flip about it, this was the previous discussion we had on realistic large break LOCA methodology, where we walked through the non-parametric statistics and sampling and the distribution curves that were used to sample the parameters.

That was submitted specifically. It's realistic LOCA methodology for application to U.S. EPR. So it's a stand-alone, but it leveraged the "approved version" of the methodology that we use for some of our operating plants.

CHAIRMAN POWERS: Okay. Just so I know what it is. Okay. Now if you're going to sample those distributions, you're sampling independently?

MR. ABEL: Right. So each --

CHAIRMAN POWERS: But why would you think they're independent?

MR. ABEL: Well, each of these -- what happens is there's even more parameters than this. There's about, there's more than about 30. For each case, we'll go through and each will have different distributions. Some are, you know, normal distributions, some are uniform distribution, and based on --

CHAIRMAN POWERS: It turns out it makes almost no difference, as long as you use high entropy distributions there.

MR. ABEL: Yes.

CHAIRMAN POWERS: It will make a difference is if there's correlation among the parameters.

MR. ABEL: Right.

CHAIRMAN POWERS: So why wouldn't I think that operating temperature and pressurized of pressure are correlated?

MR. ABEL: Right. I mean we treat them as independent, and then over the set of cases that I guess these effects would average out.

CHAIRMAN POWERS: I see no reason for me to think they would average out, if the parameters are correlated, and you change your distribution inevitably. In some of your items you're sampling, I mean it strikes me as inconceivable that initial operating temperature and pressurized of pressure should not be correlated.

(Off mic comments.)

DR. SLOAN: Dr. Powers, I'm going to say, we probably don't have the right person. We were focused more on presenting results. But if the Subcommittee members have an interest in going back to some of the questions on the methodology, we can follow up with that. So we just don't have the right staff here on the methodology.

MEMBER BANERJEE: So what you're doing, if I understand it, is the standard sort of thing what you're doing full fidelity runs, and doing more than the unusual 59, for what reason again? Can you explain?

MR. ABEL: Well, the 124 came from agreement with the staff, NRC, and the -- where that comes from is if you treat this as a trivariate case, with the three parameters, right, as opposed to the 59.

CHAIRMAN POWERS: Roughly you get 99 percent probability if you sampled 95 percent of the space when you do 124.

MR. ABEL: Yes.

CHAIRMAN POWERS: It's a huge number.

MEMBER BANERJEE: Dana, do you understand this really? I mean I've been grappling with it. I've read all the original papers now.

CHAIRMAN POWERS: That's Mistake No. 1.

(Laughter.)

CHAIRMAN POWERS: I guess I'll go through more and more.

MEMBER BANERJEE: It was to do with --

CHAIRMAN POWERS: Just read Craig and Hogg's Chapter on this. You'll understand everything you want to here. Anyway, I think it's an excellent technique for finding out what your code is doing, or if you believe your code, finding out what your core is doing. Either way, it's a wonderful tool for debugging codes, by the way, because when you see strange things happening in your distribution, you know there's probably a mistake in your code.

So yes, I mean we've used it extensively to build the RADTRAD, which is used for the 10 C.F.R. Part 100 evaluations and things like that, and right now I know that the -- I mean the joy of this is that he could -- he has 30 parameters that he's sampling. He could have 3,000, and still 124 is the right number to do it.

MEMBER BANERJEE: That is what's -- but as Shack put it to me, he said that Arthur C. Clarke's Third Law is that any new technology seems like magic.

CHAIRMAN POWERS: Well, let's see. The first time I saw this kind of technique being used was for the safety analysis of the high flex beam reactor at Brookhaven. So it's not exactly new technology. It's been in Hogg and Craig since at least the second edition. It had never been in the first edition, for all I know. But I don't, haven't looked at that.

So it's been around for quite a while, and it's just a nice, it's a nice formalism for doing things that, looking at what the spread in the results are for bearing obvious parameters and things like that. Now what kills you on this thing is that if you get high correlation, but you're sampling it as, well, your distribution isn't as spread as you, as reality is.

So you have to be very careful about choosing independent parameters, so that they're really conceptually independent from each other, because nobody understands. I mean if you try to do correlation, we'd spend the next hour discussing what this correlation means.

MEMBER BANERJEE: As you know, when I was in my youth and we developed the CSAU methodology, it was with reduced order of models using Monte Carlo, and later on Latin Hypercube. This sort of -- ACRS started to do this.

CHAIRMAN POWERS: Yes. The problem with Latin Hypercube sampling is what's of interest here is the variance, and if you do Latin Hypercube sampling, then you artificially narrow the variance. By doing straightforward Monte Carlo, then at least as you go to an infinite number of samples, you're guaranteed to converge to the true variance.

Well, with Latin Hypercube you can do an infinite number of samples, and you will always have -- I mean Latin Hypercube is a variance narrowing technique. That was why it was invented, was to reduce the variance in the results they got. So this is -- I mean it's just a very nice technique, and on top of that, the coding overhead that you pay for this is really small, compared to things like that in Hypercube sampling.

MEMBER BANERJEE: Plus it lets you use a full fidelity, of course.

CHAIRMAN POWERS: Yes. I mean you put this in some of our codes, you know, it might be 1,000 lines of code at most. I've done it with 25 lines of code. It's really a low overhead computational technique, and the results that you get out of it, because they're true Monte Carlo, then all the statistical horsepower of the sophomore statistics class can be brought to bear on the thing.

I mean you don't have to be a statistician to understand how to do the statistics on the results and things like that.

MEMBER BANERJEE: No. It's only why the results are right. That's the problem.

CHAIRMAN POWERS: Well, they're as right as the code is, you know. If the code is phenomenologically correct, these results are phenomenologically correct, because you don't perturb the code or anything here. You're just sampling the input to it. All right. Charge ahead. Show us the results. I'm dying to see the distributions.

The problem with 124, of course you can't compute density functions worth sour apples with 124. So everything you get, it comes as cumulative, which drives people nuts.

MR. ABEL: So on this next slide here, this just gives an idea of the sampling for these few parameters, and it's just to show the coverage of the 124 cases, where you get a good, even coverage between the lower limit and the upper limit. You don't have a bunch.

CHAIRMAN POWERS: Yes, you're just lucky. The people doing Yucca Mountain were forced to go to

Latin Hypercube, because the reviewers wanted to see a dot in each box along the line there, which is nonsense. I mean it's just complete nonsense, because in a true random sampling with 124, you're guaranteed that some boxes are going to be under-represented.

MR. ABEL: Right.

CHAIRMAN POWERS: But I mean you got what you'd expected.

MR. ABEL: Here we show some of the results on the left-hand side. We have the equilibrium cycle case, PCT versus time of PCT. Our limiting case for that was Case 38, which had a PCT of 1,625 degrees. On the right, we have similar, but for the Cycle 1 case and in that case, Case 85 was the limiting of 1,695.

This slide compares the total oxidation versus PCT for both equilibrium and Cycle 1 cases. You'll see for the equilibrium cycle, we are well below the limit of one percent, and that was Case 2.

The case that is circled there, that's the max PCT case, just to show you, just to give you an idea of how the max PCT case relates to the max total oxidation case. Likewise for Cycle 1, Case 63 was the limiting one at .0271 percent.

CHAIRMAN POWERS: Did you plot the

distributions?

MR. ABEL: The distributions of --

CHAIRMAN POWERS: The cumulative. I mean you can derive a cumulative distribution out of these results.

MR. ABEL: Right. We don't have the -- I don't think we have those, no.

CHAIRMAN POWERS: Oh, that's too bad. Because you get not only the distribution, but you get the uncertainties and the quantiles, and then we could sit here and yell at you a lot. No, I mean really. You absolutely need to plot out those cumulative distributions with the uncertainties in the quantiles.

That will make your case -- I mean you're arguing gee, the biggest number I got here, in which you have some faith is in 95 percent of the potential parameter space. It's up there, but you make the case really strongly with the distributions and the uncertainties in the quantiles on it, because you can set those at whatever Getachew wants you to set them at, and then make the case very strongly there.

MR. MOORE: You want to mention?

MR. ABEL: Yes.

MR. MOORE: This is Gene Moore. I also work in safety analysis, and for these two cases, for these two sets of cases, the 50-50's were about the same, and it was a 1243 for the equilibrium cycle, and 1244 for a Cycle 1.

CHAIRMAN POWERS: 50 percent confidence on the mode or the median? Who cares? We're only interested in the tails. I mean that's all that Appendix K is interested in is the tails. You've got enough data points, and that's a lot of data points there.

MR. ABEL: Yes.

CHAIRMAN POWERS: Incidentally, we are currently running now this kind of technique with 16 samples. You want to see smoke and mirrors? I'll show you smoke and mirrors.

MR. ABEL: All right, and in this slide, this is maximum oxidation for both sets of cases, and both show well below the limit of 17 percent, with equilibrium showing --

CHAIRMAN POWERS: Did you use Baker-Just for this?

MR. ABEL: What is Baker-Just -- yes, that's correct.

MS. SCHOR: No, Cathcart.

MR. ABEL: Oh, Cathcart, yes.

CHAIRMAN POWERS: So why isn't your limit down to 13 percent then?

MR. ABEL: Is that a change?

MS. SCHOR: I don't know if the Appendix K changed to Cathcart to 13 percent. I think 17 percent is still in Appendix K.

CHAIRMAN POWERS: Is has to do with how much oxygen is dissolved in the clad, and Baker-Just doesn't dissolve as much as Cathcart-Pawel does.

(Simultaneous speaking.)

MS. SCHOR: Yes. 50.46 has one set of criterias. It doesn't discriminate between Baker-Just and CATHARE.

MR. ABEL: Cathcart-Pawel, yes.

CHAIRMAN POWERS: It should, the weight of all. Then we'll make you take into account hydrogen embrittlement as well.

DR. SLOAN: We're watching that.

MR. ABEL: Okay. That's all I had for the results. Are there any questions?

CHAIRMAN POWERS: I'm disappointed. I wanted to see the distributions.

MEMBER BANERJEE: Well, we can ask them. Ask them.

(Laughter.)

MR. ABEL: Okay. These are some previous

questions that ACRS asked. The first one was regarding what the upstream conditions were for Moby Dick test 3141, and the second question was regarding how SRELAP5 treatment treats nitrogen during critical flow. So for the Moby Dick experiment, this was a subcool conditions at inlet with the inlet pressure of about 81 psia at the temperature of about 96 Fahrenheit.

For how RELAP deals with non-condensables for critical flow, it's based on the ATM model, with the phases in thermal equilibrium. The pressures are based on partial pressures as steam and non-condensables. This is Gibbs-Dalton mixture assumption, with the condensables treated as an ideal gas.

CHAIRMAN POWERS: Can you really do that? There's fairly strong interaction between steam and nitrogen.

MEMBER BANERJEE: It's basically what the chemical -- they picked this up from the chemical industry now. Whether it's accurate or not, we don't know. But Hans Closkey and people did some experiments actually.

CHAIRMAN POWERS: There's some fairly definitive work that's been done on the steam nitrogen ferial equation.

MEMBER BANERJEE: Yes. You're probably talking about something that people have not considered, because they consider everything in these situations as an ideal gas --. So whether it's accurate within the sort of really large inaccuracies of any of these predictions.

CHAIRMAN POWERS: And if you're going to calculate critical flow, does it make a difference?

MEMBER BANERJEE: It probably, you know, at high pressures and stuff, of course it does.

CHAIRMAN POWERS: I mean I would think it would, because --

MEMBER BANERJEE: But what they're doing is just taking relatively low pressure data, where more or less I don't know with steam. If I remember, these were with -- the experiments were with -- it's so long ago. It was done under the emergency relief program for chemical reactors. Hans and company, you know, his crew, Bob Henry and all, they did quite a few experiments, and I'm trying to think back now. Some of these reactors produced gas, as well as, you know.

CHAIRMAN POWERS: Sure.

MEMBER BANERJEE: You've got a non-condensable with a vaporizing solvent. For the life of me, I can't remember what the fluids were. It was relatively low pressure, and they used an ideal gas. They used the -- assumption.

CHAIRMAN POWERS: I mean if you're --

MEMBER BANERJEE: This is, of course, at 600 psi.

CHAIRMAN POWERS: Yes. It's not very high pressure.

MEMBER BANERJEE: Well, it's not low either.

CHAIRMAN POWERS: 1.4 megapascals, something like that.

MEMBER BANERJEE: No, four megapascals.

CHAIRMAN POWERS: Four megapascals. Ehh.

MEMBER BANERJEE: He likes them in sort of thousands of megapascals, like drilling into the pre-salt region in the -- you know, it's like 20,000 atmospheres down there.

MR. NITHIANANDAN: But not great for the non-chemical counts and the pressure is about 50, 60 psis.

MR. ABEL: Is that --

MR. NITHIANANDAN: Yes, because you know, you are in a different region.

MEMBER BANERJEE: Yes, because you've got to get rid of your --

(Simultaneous speaking.)

MR. NITHIANANDAN: So it's a short period you can go through a critical flow. But most of the time it's in non-critical conditions.

MR. ABEL: And essential the, you know, the vapor properties are obtained from steam tables and non-condensables gas state equations, and the remaining portion of the critical flow calculation is similar to what's done when non-condensables are not present, in terms of --

CHAIRMAN POWERS: That's surprising, because you've essentially -- I mean it's just an ideal gas. So what else would you do?

MR. ABEL: I think that's all I had.

DR. SLOAN: May I suggest we switch gears and bring up a couple of other presenters, unless there are more specific questions.

MEMBER BANERJEE: They're not a local, limited plant, right?

CHAIRMAN POWERS: No.

MEMBER BANERJEE: What's the margin?

CHAIRMAN POWERS: Lots of margin, a ton of margin.

MEMBER BANERJEE: It's going to be DNB limited.

CHAIRMAN POWERS: So now they put humongous big steam generators on this sucker and jack the power up by another 25 percent.

MEMBER BANERJEE: The words out of my mouth.

CHAIRMAN POWERS: Okay. Well, let me do say that I appreciate your doing a non-parametric analysis. I think that is a tool that can be used to benefit a lot of these things. As I say, I in fact use it for debugging codes, you know, searing for phenomenological error, because if your distributions come out looking funny, or because you can sample weird combinations of parametric values you never think to type in yourself.

If the code starts behaving funny, then you've got probably a mistake. But it would nice to plot out the distributions, the actual distributions, rather than just listing your peak, because you don't know where that peak actually is in the overall frequency.

Now it's probably, I would guess, up around 98, 99 percentile for the number of samples you took. But you don't know for sure, and I think you can make a case more strongly with the distributions.

DR. SLOAN: I will say it's nice from my perspective to hear positive words about the non-parametric statistical methods. I don't hear it very often.

CHAIRMAN POWERS: I don't -- well, no. It's terrific, because what you can do is you can go in there and you can say okay, I don't know what the distribution is of these parameters. I took it as uniform. So I'll make it a beta or I'll make a Gaussian or anything like that. You can show that it makes almost zip difference, as long as you don't, it's not some weird, stylized distribution. It makes almost no difference whatsoever.

It takes a whole raft of debate and argument that's unresolvable because you don't have any data on where they are in those distributions, and you can never sort that all out. It takes it right off the table. Plus you're not presuming what the distribution and the results are. That's what non-parametric means. If you don't presuppose what the distribution is; you let the results dictate what the distribution is.

That takes another whole great big debate, an unresolvable debate off the table, and you end up with a distribution where you can talk about levels of conservatism there, in fairly quantitative terms. You know, yes. I think it's a terrific technique, and like I said, the first time I saw it used in the reactor debate was actually for the high flux steam reactor, and by the folks up at Brookhaven.

I adopted it for work I did for the NRC and for developing the RADTRAD code. I mean it gives you a chance to do things that ordinarily we end up arguing at the end of the results and doing sensitivity studies that nobody understands and things like that. You know, all your debate is on what those ranges are for your sample parameters, and whether there's a correlation among them.

If there is, by the way, the technique still works. It's easy to do correlations in there, and we've explored multiple methods of doing the correlations, and in the end, I think we can show that your choice of metric for correlation makes no difference really in the results at all. But correlation does make a difference. But it's very easy to incorporate correlation.

MEMBER BANERJEE: By the way, you should read a paper by my illustrious predecessor, Graham Wallis. Have you read the paper by Nutt and Wallis?

DR. SLOAN: What's the date on the paper, Dr. Banerjee?

MEMBER BANERJEE: Two, three years ago.

MR. ABEL: I don't believe I have.

MEMBER BANERJEE: On this thing. So if you are interested, as I'm getting interested now, because we have to use this thing. So we have to do something to understand it.

CHAIRMAN POWERS: It's pretty straightforward stuff.

MEMBER BANERJEE: Well, it's not so obvious, because it came out of a quality assurance paper really, you know. It was the tolerances and things, and how you should sample this stuff, and then extended it to two or three measures and things like that.

The part of it which is non-intuitive to me is when you've got a very large number of parameters, and you sample the space, how you can get sort of confidence in the results.

CHAIRMAN POWERS: What you're saying is that the sample that you're growing comes from a particular but unknown distribution?

MEMBER BANERJEE: Yes, completely.

(Simultaneous speaking.)

CHAIRMAN POWERS: You don't care what made that distribution.

MEMBER BANERJEE: No.

CHAIRMAN POWERS: It could be ten to the fifth on certain parameters that created that distribution, and you're just taking the samples out and finding out what does that distribution look like from the samples themselves, the way you would do sampling on anything.

MEMBER BANERJEE: Well, that's the analogy.

CHAIRMAN POWERS: Exactly.

MEMBER BANERJEE: Yes, but why it works, I still can't figure out, because each of these parameters comes with their own distribution, you know.

CHAIRMAN POWERS: Well, I mean that's just the central limit theory that's coming to play there.

MEMBER BANERJEE: I have sit down and work through the details, and once I've satisfied myself --

CHAIRMAN POWERS: Then you'll be happy.

MEMBER BANERJEE: Then I'll be happy.

CHAIRMAN POWERS: But like I said, I appreciate you doing that, though. That's an important technique. You want to dial down the temperature a little bit? I think they're sweltering under the klieg lights that are coming down.

MEMBER BANERJEE: There's a special air conditioner.

DR. SLOAN: I thought. You missed my conservation with Dr. Powers, and I was thinking he does this on purpose.

MR. WIDMAYER: The presenters on Tuesday said they felt it was an advantage.

(Simultaneous speaking.)

DR. SLOAN: Probably they're very cold temperatures.

MR. WIDMAYER: The presenters on Tuesday said that they liked it, that they had air conditioning right in their face.

DR. SLOAN: Wow.

(Laughter.)

CHAIRMAN POWERS: And in fact it cooled down a little bit for Sloan, because she's a little hothead.

MR. WIDMAYER: A hot spring behind them and everything. They said it was nice having the air blowing on them. You want us to turn it down or -- turn the heat on.

(Laughter.)

CHAIRMAN POWERS: So it's the Don and Lisa show

MR. ROWE: Yes. Don Rowe, Lisa Gerken, the young lady on my right.

CHAIRMAN POWERS: I would have never guessed.

MR. ROWE: Never would have guessed.

(Laughter.)

MR. ROWE: Let's see. Let's have the next slide.

CHAIRMAN POWERS: Oh no. You don't get to start that easy.

MR. ROWE: I don't get to start that easy?

CHAIRMAN POWERS: Oh no, no, no, no. We've got rules here.

DR. SLOAN: Background and personal history.

MR. ROWE: I was going to do that next. I'll move right here --. I'm Donald Rowe. I've been involved with the nuclear business in reactor safety and reactor core thermal hydraulics all of my career.

I have a Bachelor's degree from the University of Washington in Mechanical Engineering. Did a Master's in Nuclear Engineering at the University of Washington. Did a Ph.D. at Oregon State

University.

I've had some tours through the Knolls Atomic Power Lab, Pacific Northwest Laboratory in Richland, and worked a lot with Exelon Nuclear at that time. That kind of dates me.

CHAIRMAN POWERS: And they let you come into the --

MR. ROWE: Come back after this? Yes. And I've basically started a private business partway through all that and been doing that for quite a few years, and I've been doing consulting work with a variety of organizations, including AREVA and all of its predecessors for quite a while.

So my background is in reactor core thermal hydraulics, reactor safety. I've done experimental work, I've done co-development work, I've done theoretical work. So it's kind of a spectrum of activities.

MEMBER BANERJEE: Rower and Associates still exists?

MR. ROWE: Well, yes. I'm the associate.

(Laughter.)

MR. ROWE: But it's been a full run, yes. It's been very good. Okay. Now we get to the next slide. I just wanted to just outline the scope of what we're going to be talking about. Mixture level, and what that has to do with is long-term core cooling, and boron precipitation we're going to talk about today.

Boron dilution we're not going to talk about, and GSI-191 we're not going to talk about. Those will be, those two items will be a future discussion. Okay, next slide.

MEMBER BANERJEE: When will those last two topics be discussed, Sandra or anybody have a date on this?

(Simultaneous speaking.)

CHAIRMAN POWERS: --when you'd be obligated and out of the country.

(Laughter.)

DR. SLOAN: We're still in the process of addressing the staff's questions on these topic areas. So we have to finish our part of information that's due to the staff, and then the staff has to review that information.

MEMBER BANERJEE: Okay. So you've submitted your --

DR. SLOAN: Part of it. Part of it we're still working on in those areas.

MR. ROWE: Part of it's submitted and part of it's underway.

DR. SLOAN: Yes. That's why this is Part 2 or Group 2 of Chapter 15. Group 3 of Chapter 15 will have these elements. This is what's left, now that we've gone through two groups.

MEMBER BANERJEE: Oh, we'll find out.

MR. TESFAYE: Just for information, I think boron dilution is an open item in this SE. So I think it's a Phase 4 activity.

DR. SLOAN: Yes.

MR. COLACCINO: And Getachew, this is Joe Colaccino, the branch chief for the EPR Projects Branch. Just so that everybody's clear in the room on where we are, especially with the GSI-191, I think that's very important, and thanks for the open item and for boron dilution. But GSI-191 is what we've decided to do with that is to take that, to assume that it's going to be completed within Phase 4.

So where we would probably see it is later on, some time next year, presumably in the early part of next year. So we will finish out the Phase 2 safety evaluations for the entire review, with the exception of this particular review area, and that encompasses portions of Chapter 6 and Chapter 15. I think it's 15.6.5 and 6.2.2, if you need the numbers.

So you know, a very specific thing. We've documented this and communicated this to AREVA. That doesn't mean, of course, that the Committee can't ask for the applicants to come and talk about what their design philosophy is at any time, or for the staff, for that matter, come and talk about that.

CHAIRMAN POWERS: Yes. That was kind of what we were thinking of doing, is having kind of a preview or heads-up kind of discussion on it, whenever we can arrange to do it.

MR. COLACCINO: Okay. I hope that's helpful.

MEMBER BANERJEE: Yes, that is. It gives me a time line.

CHAIRMAN POWERS: And by the way, I think you weren't here, but I think we're still good for the November meeting.

MR. COLACCINO: Fantastic. Okay, thank you.

MR. ROWE: Okay. This topic on long-term core cooling is one of assuring that the core can be covered with a two-phase mixture level throughout a long period of time in the post-LOCA period. The analytical approach that we've adopted is a quasi-steady static balance approach, and this is the basic idea was developed at INEL many years ago under sponsorship of an NRC program.

The basic idea of the model assumes that the primary system is rather quiet, negligible, dynamic behavior. In other words, it's reached a rather quiescent state, and there's not a lot of dynamics going on. It's basically they're cooking and boiling.

The system pressure drops throughout the system are based on steam flow and hydrostatic heads. There are no temporal terms. These are not transient equations. It's basically given a power in the reactor. You can determine what the flows, pressure drop levels are all about.

So I'll be showing you some examples of results on this in time. All that's doing is following the power and decay table. So we're not doing a transient calculation. The basic bottom line on this whole thing is that the two-phase mixture level is there, and it does assure that the core is maintained with an ability to cool for the long term.

I might mention also in the analytic approach, we have not considered hot leg injection, and we have not considered boron concentration. We'll talk about those things a little bit later. Okay, next one.

CHAIRMAN POWERS: You might show what you mean by boron concentration. The actual moles per liter you haven't considered, or you haven't considered boron concentrating in some --

MR. ROWE: Boron concentrating. Boron concentrating in the --

CHAIRMAN POWERS: It just sits there and does its thing. It doesn't --

MR. ROWE: Okay. Here's a cartoon that shows the basic modeling concept. You'll see some water levels in here, and there's safety injection going into the system. It's assumed that there is, and there is ample safety injection from the low pressure cooling injection, all that stuff, and anything excess goes out the break.

So we're not looking at levels in time through this process. Notice that there's the -- down here in the loop seal, there's assumed to be a level of water, and we have some evidence from experimental work done at Westinghouse as to what the water levels might be in a loop seal with different volumetric flows of vapor. We take advantage of that, and so we define what the water level might be in the loop seal when the steam is being vented.

Notice also some bubbles under the pump here. When you have a vented loop, there is vapor going up this vertical leg of pipe, and that contributes to the or is part of the hydrostatic head aspect of this situation. In fact, with the bubbles there, there is reduced head, reduced head there.

Then the downcomer over here, with its head of water, actually they realize nearly the full head of water. So this nanometer balance is the key to this whole idea. So drop down into the -- come down the downcomer, you go into the core, and I just noticed here a path. I'll talk about the paths in a minute.

But then the water enters the core. Depending upon whether it's sub-cooled or not, you do get the boiling, and there is a collapsed mixture level, I call it here Z-1. Z-1 is always, in this particular model, very related to the top elevation of the loop seal. In other words, can you get water into the loop seal.

Now what's illustrated here is a vented loop. I don't consider it a cleared loop; I consider it vented. You can have vapor going through this loop seal and not have it blow out. So there's also loops that are not vented. Now I assume all loops in the plant are identical, for purposes of this analysis. You either put in the bin of a vented loop or a non-vented loop.

When you have a non-vented loop, this loop seal is full of water. There is no vapor going up this loop here, and you have a water level on this side. Only when this water level gets depressed down could you kick another loop into the vented column.

So the logic of the calculation, you assume that there's one vented loop, and if you can't satisfy the pressure drop relationships, you vent another loop. Keep doing that at each power, and then determine what the status of the vented loops are.

There's a particular situation of some relevance to this long-term scenario, and that is when you have the water level exactly right here and there is no steam going through, the loop flow has gone to zero, and at that point you have -- notice this is all full of water right here, and it cancels out the water head that's in the downcomer.

So you have the minimum available liquid head in the downcomer, and that's going to lead to the closest approach to uncovering a core that could exist. It turns out it's at very low power, and for all practical purposes it's not of concern, but it's not an identifiable event.

Let's see. We have some paths here. We have a path through the loops, where you have steam flowing through the loops. We have the steam flow resistance. That's one of the resistance paths that's modeled. We go through a pump down here, and we assume that the pump is a locked rotor. So we basically get to the highest resistance that we can reasonably define for the loops. So that gives us fairly high resistance path.

With that resistance path, depending on the steam flow rates, you can depress the collapsed level of the core. Path 1, this is a bypass between the upper plenum and the downcomer. Now this is a path which in many plants you just call it the hot leg gap. The EPR has a special design feature that allows flow under normal operations between the top of the downcomer and the upper plenum, and they call these the downcomer spray nozzles.

These are, there's 32 of them. They have about a half-inch diameter hole in the nozzle, and so they are always open. So even if the hot leg gap closes, there is still a path that can be opened. Variable to be sure, if you consider both these two parallel paths that can vent steam.

But this is included in the modeling, and you can turn it off also. So this is something that can be handled. We have the path through the loops. Okay. We also have the path down at the downcomer up through the core and to the collapsed level. This is a hydrostatic head consideration, and we consider losses basically from the downcomer to the upper plenum. We assign that at the core inlet.

We don't consider acceleration by change of days. We don't consider the pressure drop because of change of density. These are all small compared to the hydrostatic heads involved in the problem, and compared to the loop frictional pressure drop.

Okay now, one of the most important things is that if you have a collapsed level defined, and you have a core power and it's boiling, you can have a level swell. When you have boiling it's like a pot of water; it tends to rise up, and depending upon the amount of power, you can get various amounts of boiling in the core.

Now for the EPR, all other things being kind of normal, let's say, in this scenario, you only have to push the two phase level up 30 millimeters, to assure that the core is covered. You don't need much boiling in this core to assure covery, and when it's at high power, high decay power, the two phase level reach into the hot legs. You'll see an example of that. So we have ample margin to cover with this approach.

Let's see. Did I miss anything here? Okay. I'll show you an example of a typical result. What you have here is basically I have level and I have time from full power shutdown in days. Now again, this is not a transient calculation. I'm following decay powers out of a decay curve. So that I could put on there also decay power. They're interchangeable.

Three things to notice here. Okay, here's the top of the core, top of active fuel, and this lower set of points are the -- that's the collapsed level. You notice that the collapsed level is actually below the top of active fuel, but because of the level swell, the boiling in the core, it swells up, if you will, and it reaches -- here, the mixture level reaches the level of the hot legs.

This little dip here corresponds to this particular change of the number of loop seals. Starting from here, if you go out, you would have three loop seals venting and then two and then one. Here's this transition that I talked about, where you are at the minimum possible depression of water level in the core.

This happens to be out about ten megawatts, and for all practical purposes it's something that would not occur. The value chosen for the resistance through the bypass gap is such that this occurs -- this one is shown at what is estimated to be the highest power that you could achieve and have this transition. If you took the other end of the resistance for that bypass, it's well out on the right side of the graph.

So what basically shows here it brings up -- it shows a lot of the parameters. It illustrates some of the phenomena. It addresses the number of loop seals that are venting steam, it considers this transition, and we've run this through all sorts of parametric studies. In fact, all of this information is not in the FSAR. It's in RAI responses.

The staff asked us to do a lot of parametric calculations with this model and this particular application. We vary density, we vary axial power shape. We do a lot of different things, and for all practical purposes the results keep coming out looking very much the same. Yes, there are variations, but they are of secondary importance to the basic result that says that the core is well-covered.

CHAIRMAN POWERS: You can change the core all you want to in this model.

MR. ROWE: Yes. One of the things --

CHAIRMAN POWERS: It doesn't make any difference, because you've essentially got a mixed cup calculation.

MR. ROWE: Got which?

CHAIRMAN POWERS: You've got a mixing cup calculation, so that you can do the -- the power profile can change any way it wants to.

MR. ROWE: Yes. If you invert the axial power shape, you change the level swell. You don't see that these high power levels. If you drop down to lower power, then you can see where changing the axial power shapes affects it, whether the bottom or the top peak.

CHAIRMAN POWERS: I guess you're right. The level swell might be able to detect something. But otherwise, you're fairly insensitive with this model.

MR. ROWE: Yes, it is, and also, from the point of view of the phenomena, you don't have to have much level swell. If your collapse level is near the top of the core, you don't have to go very far. That's a pretty good result. So one thing is very important. Bob Salm will shoot me if I don't show you this line right here.

MR. SALM: I was getting ready to do that.

(Laughter.)

MR. ROWE: He's taking aim, and this whole thing out beyond an hour may be -- it's an interesting exercise. It may be theoretical. It's informative. Putting reality at one hour, hot leg injection is turned on in the APR, and the world changes a lot when hot leg injection starts. It shuts down the steaming, fills the core from the top and --

CHAIRMAN POWERS: Don't worry. The operator will make an error and forget to turn it on, so --.

MR. ROWE: We hope not, we hope not. So anyway, this is -- these are what the results look like. This is what we've been looking at, and the staff has seen a lot of these things already, and we've had a lot of discussion about this in the modeling.

Anyway, it's a simple model that illustrates phenomena, without having to get out of existing code. Simple and easy to do. Any questions on this point before I wrap it up? Dr. Banerjee, any? Okay, all right.

So what are the results and conclusions here? We conclude that the core is covered by a two phase mixture in the post reflood period. High two phase mixture level followed with full power LOCA. Modest two phase mixture level following a lower power LOCA. If you don't have the power there to cause the boiling, the levels are lower. But even going way out in time at low K powers, we still get ample coverage.

Two phase mixture level is the thing that assures long-term cooling in the core. It's a boiling pot wells up. Where the important features of the EPR design is the shallow loop seal in its elevation. So top of the fuel is only 30 millimeters below the top of the loop seal. So it doesn't have to go very far to get covered. That concludes what I have to say.

MS. GERKEN: My name is Lisa Gerken. My introduction is significantly shorter than Don's. He told me to do that. I have my Bachelor's degree --

CHAIRMAN POWERS: It's got to be exactly the same length, because the topics you have to cover are exactly the same.

MS. GERKEN: My Bachelor's is in Mechanical Engineering from Penn State. I've been with AREVA since then for about five years, and primarily working on the U.S. EPR during that length of time. I'm going to talk --

CHAIRMAN POWERS: So you're uncontaminated with all this Exelon and --

MR. ROWE: This old stuff, yes.

CHAIRMAN POWERS: So we might believe you, as opposed to Don.

MEMBER BANERJEE: Because he assumes a steady state. Now we know that these things are up and down.

MR. ROWE: Oh it is, yes. It's chaos.

(Simultaneous speaking.)

CHAIRMAN POWERS: And a mechanical engineer is never qualified to discuss chemical phenomena.

MS. GERKEN: Okay. Boron precipitation is what we are talking about. During the full boiling phase following a LOCA, the boron could concentrate in the reactor core if countermeasures are not taken. If the concentration reaches the solubility limit, then boron precipitates out of the solution and potentially causes cooling channel blockage.

The U.S. EPR has two primary actions which the operator can take. As Liliane mentioned earlier, there is the automatic partial cool-down, which is initiated on the SI signal. Following this, the operator will initiate the full cool-down.

For smaller breaks, which didn't depressurize from the break alone, this allows the RCS to depressurize and reach the LHSI shut-off head. When the LHSI comes on, it can refill the RCS and allows for a natural circulation to reestablish, thereby controlling the concentration in the core from the smaller breaks.

For larger breaks, we have the hot leg injection, which as Don said earlier is initiated at 60 minutes. This redirects approximately 75 percent of the LHSI flow into the hot legs, while maintaining all of the MHSI and the remaining portion of the LHSI into the cooled legs. This flushes the core and controls the concentration within the core at this time.

An additional feature for the U.S. EPR in terms of boron precipitation is the use of a 37 percent enriched boron. This allows for the RCS and the IRWST concentration to be lower, while maintaining the same reactivity control.

MEMBER BANERJEE: The time to connect the LHSI through the hot leg, is that fixed at 60 minutes, or is that an operator action which is --

MS. GERKEN: It's an operator action.

MEMBER BANERJEE: So they can decide when to do it, or is there an uncertainty associated with that?

MS. GERKEN: The operating procedures aren't written yet, but it will be initiated at 60 minutes following --

MEMBER BANERJEE: Always? I mean --

MS. GERKEN: Following when certain criteria are met.

CHAIRMAN POWERS: Not 59, but 60.

MR. ROWE: So Bob, is that fixed hard at this time?

MR. SALM: Yes. This Bob Salm from AREVA again. 60 minutes is the time that's used in our Chapter 15 analyses. So that establishes the outer limit. But the operator could initiate it earlier. I mean there's nothing -- I mean you wouldn't want to actuate this during blowdown, but you know --

MR. ROWE: You can't.

CHAIRMAN POWERS: Probably not.

(Simultaneous speaking.)

MR. SALM: But you know, once you've gone through reflood and you're out into the later phase of the event, the timing is insensitive. Just so it's done by 60 minutes, and this accomplishes more than just the boron precipitation.

It's also necessary for the containment analysis, for the containment pressure. We need to suppress steaming, because the containment does not use sprays for design basis events. So there's a number of reasons to actuate it by an hour.

MEMBER BANERJEE: Why do you leave it as an operator action then, I mean, instead of the sprays? It has other functions as well, right? Doesn't that, why doesn't it happen automatically?

MR. SALM: Well, there's -- I mean an hour is plenty of time for the operator to realize that he's had a LOCA, and take action. So --

CHAIRMAN POWERS: It might come to his attention in an hour.

(Laughter.)

CHAIRMAN POWERS: Gosh, there's something wrong here. I wonder what it is?

(Simultaneous speaking.)

MEMBER BANERJEE: They may not --

CHAIRMAN POWERS: Well, they knew that there was something wrong.

MR. ROWE: The pressurizer level is --

CHAIRMAN POWERS: That's right, yes.

MR. WIDMAYER: Speaking of hot, are you guys getting hot yet?

MR. ROWE: It's warm, yes.

CHAIRMAN POWERS: Well, it's getting too warm here. Could you turn it down --

MR. WIDMAYER: Well, one way or another.

MR. ROWE: Let's go back to cooling.

MS. SCHOR: I want to ask a question. Hi, I'm Liliane Schor again. You know, you want the operator to take these measures, not automatic, because there are breaks for which you -- very small breaks, for which you don't want to turn on the hot leg injections. So you would like operator intervention for such an action.

MEMBER BANERJEE: So the operator would have to know that it's not a small break?

MS. SCHOR: Correct, and there are -- we didn't write yet for the EPR, and we were planning to do additional analysis. But there will be not only the timing; there will be also other factors that will alert the operator, either to start handling injection or not.

MEMBER BANERJEE: What would happen if the operator injected for a very small break? What would be the adverse consequences?

MS. SCHOR: I don't think there will be no adverse consequences.

MEMBER BANERJEE: There would be no effect at all, right?

MS. SCHOR: Correct. I mean no difference.

MEMBER BANERJEE: So why wouldn't you do it anyway? What difference would it make?

MS. SCHOR: Oh, I need to think about that.

MEMBER BANERJEE: Okay. The less you want the operator to do in this mess, the better. Never mind.

CHAIRMAN POWERS: That may not be true from a human factors view. We don't want operators standing around with time on their hands.

MEMBER BANERJEE: That's probably the most dangerous thing. Yes, I agree. In a chemical flood, one of the most dangerous things is to have operators standing around, because they invariably do something wrong.

MS. GERKEN: Okay. U.S. EPR analysis is essentially a boiling pot analysis, in which the water boils off the core and is replenished with borated SI water. The steam exits through the hot legs and leaves all the boron in the core. The concentration rises.

Without crediting hot leg injection, we evaluate this rising concentration, and look at the time at which the concentration reaches the solubility limit. Again, we look at the concentration rise without crediting the hot leg injection.

CHAIRMAN POWERS: When you say boron, you have a mixture of borate and boric acid. What's that mixture?

MS. GERKEN: Can you repeat the question?

CHAIRMAN POWERS: You have in the solution a mixture of borate ion and boric acid, sitting somewhere on its equilibrium. Where are you sitting on the equilibrium?

MS. GERKEN: I'm not certain.

CHAIRMAN POWERS: So how do you calculate the solubility limits?

MR. ROWE: You're way down on, you're very low solubility if you concentrate too hot. You're worried about getting to the precipitation limit. But you're very low circulating in the system.

MR. SALM: This is Bob Salm again. I mean that's taken into account in determining the limit for a given temperature, but for what Lisa's doing, she's looking at what is the concentration that's actually reached, just through the steaming in the core, the volume of liquid that is active in the mixture and that end of it.

CHAIRMAN POWERS: But the solubility, I mean the borate is relatively soluble and the boric acid is relatively insoluble. So what's the mixture? I mean how does she know to say I'm getting precipitation?

MR. SALM: I'm afraid we don't have the right people here to answer that question. We'll have to get back with you.

CHAIRMAN POWERS: This is all at 14, at one atmosphere pressure? So entrain in the boron is truthfully negligible?

MR. SALM: We don't credit boron being entrained. It all stays in the solution.

CHAIRMAN POWERS: At one atmosphere, the entrainment in boron you're going to get is in fact when your bubbles come up and burst, they're going to throw off little droplets that are going to dry out. That's the -- you're going to get some entrainment, but it's trivial, and there's no vaporization at one atmosphere to speak of at all. I mean it's in the PPM kind of levels.

But it seems to me that the mix between how much of the boron is present as borate, and how much is present as boric acid is what you've got to know, in order to calculate the precipitation. It seems to me. I mean I don't know. I haven't tried to do this calculation either. I guess I will, but --

MS. GERKEN: Okay. The key assumptions for our analysis is that the steaming rate is determined by latent heat of vaporization at atmospheric pressure, and the ANS 1973 Decay Heat Standard increased by 20 percent. There's no credit for inlet subcooling. The injection rate is equivalent to the steaming rate, and therefore we have no increase in the volume throughout the analysis.

The injection concentration equals the maximum concentration by assuming all combinations of single failures and preventative maintenance. Additionally, this injection concentration assumes that the EBS system, which is a manually initiated system, is started at the same time as the SI.

The initial core concentration is also set equal to the injection concentration, and we answered RAIs on this to evaluate whether or not the flashing from the large break LOCA event would actually --

CHAIRMAN POWERS: What is your injection concentration?

MS. GERKEN: I don't think it is. It's 2051 PPM, and like I said in the RAIs we answered, to make sure that this statement here is conservative, and it was. Then there's no entrainment of boron in the steam. All the boron stays in the concentrating region.

Our concentrating region is defined as the region between the lower support plate and the bottom of the hot legs. Using this definition, we took the volume of water from the end of the limiting large break LOCA transient, as representative of the conservative post-reflood volume. Then we hold this volume constant throughout the entire transient.

Additionally, we used the mixture model to show the conservatism in holding this volume constant, and I'll show that in a few slides. This figure is the FSAR figure. It's the results from the analysis.

The horizontal solubility line is actually a mixing limit, which is based on injecting water at the tech spec minimum injection or IRWST concentration and boiling at 212 degrees F. It's over 30 percent below the 212, the pure 212 degree limit.

As you can see, if no countermeasures are taken, we have 1.74 hours until you would reach the solubility limit. It's three-quarters of an hour greater than when we would actually initiate hot leg injection.

This figure is a similar figure, except that it shows the comparison of using the mixture level model, which Don described, and the constant volume approach. The constant volume approach is here on the green line, and it's the one and three-quarter hours. Whereas actually allowing the volume to increase as the decay heat decreases gets us up to the 3.3 hours. So it's a substantially greater time.

MR. SALM: This is Bob Salm again. The volume is sustained the same, but the mass in that volume is increasing, because the void is decreasing. So the volume is the same, but the mass is different.

MR. ROWE: Increase the volume or just the fact that it's decayed power, it's going down, you get more liquid in the volume, or do you actually increase the volume? That's a detail we have to check.

MS. GERKEN: Okay. In conclusion, for the very small breaks, the continued depressurization allows the LHSI to come on, refill the system and reestablish natural circulation. For the larger breaks, with hot leg injection initiated at 60 minutes, and with the redirection of over 75 percent of the LHSI, flushes the cooler and maintains the concentration in the core.

Then the results from our analyses show that there is a substantial margin between the actual initiation of hot leg injection and the time you had reached the solubility limit.

MEMBER BANERJEE: What do you think is the uncertainty in that 1.74 hours?

MS. GERKEN: I wouldn't know how to quantify that.

CHAIRMAN POWERS: You would if you used a non-parametric method.

MEMBER BANERJEE: You have a model. You could use a non-parametric of some sort. It doesn't matter what, and the model can be as simple or complex as you'd like. But what Dr. Powers is suggesting you take the inputs and the model parameters, and arrange them over whatever is a reasonable range and see what it does, the outcome.

Because if it comes out that 70 is like half an hour or more, then you don't have such a big margin, right?

MS. GERKEN: Yes, but we're using conservative assumptions. So if you started to vary things, you would also vary things that causes interactions.

MEMBER BANERJEE: Are they all conservative? Yes, are they all conservative, that you would move them all to longer times?

MS. GERKEN: The key assumptions are made in the conservative directions, yes.

MEMBER BANERJEE: So do you have to take into account anything to do with the mixing volumes in your assumptions?

MS. GERKEN: Yes, we have to make an assumption about what the volume is. I mean we looked at --

MEMBER BANERJEE: How much do you assume?

MS. GERKEN: We assume value from the limiting large break LOCA Transient, but we also looked at all of the 124 cases that were run, and looked at to see where those lie. There was a few that were below, at the very end of the transient, but we ran those out in time, and we're sure that all of the volumes increased well above our initial assumption.

MEMBER BANERJEE: Well, can you just lead me through where those volumes are?

MS. GERKEN: Oh dear. This somehow or

another, the red box got moved. So don't pay too much attention to the red box. The red box is actually from here up to the bottom of the hot legs, which is right there.

MEMBER BANERJEE: Right. So there is some part of that which you're assuming is an area in which the concentrating occurs, the volume in this, right? Then is there any communication with the lower plenum area?

MS. GERKEN: There is, any time we account, we take in the region that's above the lower support plate, which is listed here as the lower plenum. There's some controversy over the use of the lower plenum, and that's -- normally when it's discussed, that also includes the lower head. But we're only talking about the volume which is above the lower support plate.

MEMBER BANERJEE: Which is always well next?

MS. GERKEN: Yes, and it comes -- after the large break LOCA, you're going to have the recirculation, which is coming up and coming down through the heavy reflector, the guide tubes and the lower power peripheral regions. That's communicating with this, what's termed here as the lower plenum, and back up through the average core and the hot readings.

MEMBER BANERJEE: So there's no sharing of the boron with anything lower than that?

MS. GERKEN: Not in our assumptions. Not in our model, no.

MEMBER BANERJEE: Okay.

MS. GERKEN: But that's not to say that if there's testing done that show as the density increases, that entire volume can contribute into the mixing. I mean as the density increases --

MEMBER BANERJEE: And one of the issues is how much of it is not clear. The reason you say this is well-mixed is you've got denser flow coming down to the overall recirculation pattern.

What about, do you think there's a region, you know, that's still going up, that's still going down, that could be a region where there isn't very much flow, if anything happens there?

MS. GERKEN: No. In the core, you're going to have the mixing from the lower power regions in the center. So that region is going to be well-mixed.

MEMBER BANERJEE: Well, yes. But the core, essentially in the center, there's upflow right, and there's down flow.

MS. GERKEN: Right, and then there's cross-flow.

MEMBER BANERJEE: And there's cross-flow. So do you think that the cross-flow is there in all regions, that there can't be any accumulation in certain regions of the core?

MS. GERKEN: Yes, but Nithian, do you have something to say?

MR. NITHIANANDAN: Yes. This is Nithian again. Most of the tests we've seen -- the cooling period from the ECTF. You know, they have done very little instrumented --

MEMBER BANERJEE: Right.

MR. NITHIANANDAN: And showing during the post reflood. But it would be the flow going up in the hot tunnel.

MEMBER BANERJEE: Right.

MR. NITHIANANDAN: And coming down, and it's available for cooling into the central tunnels.

MEMBER BANERJEE: Yes.

MR. NITHIANANDAN: So there is no stagnant water.

MEMBER BANERJEE: There is no stagnant water?

MR. NITHIANANDAN: -- at least from the

CCPL --

(Simultaneous speaking.)

MEMBER BANERJEE: Do you assume somehow that the pattern is oscillatory, because if you don't have an oscillatory pattern, you get --

MR. NITHIANANDAN: Yes. They have the DP measurements at the different levels, and all the tests we have seen so far are done under the different power levels. So there's a very well-mixed and --

MEMBER BANERJEE: So the upward or the downward must be meandering?

MR. NITHIANANDAN: Yes.

MEMBER BANERJEE: Yes, okay. Otherwise, you will get a dead zone?

MR. NITHIANANDAN: Yes.

MEMBER BANERJEE: Which would be your conservative assumption, not in that it did not have a meandering plume, what would happen? Now admittedly, the experiments probably support that. I'm just asking you is there a problem, then, that you run into high concentrations in certain regions? You're not taking any credit for the lower plenum right, at the moment? Which is sort of unusual.

MS. GERKEN: Anything above the lower support plate is credited. So that's the portion of the lower plate.

MEMBER BANERJEE: How much? What's that distance?

MS. GERKEN: The height of it I'm not sure. I know the volume of it. It's about 120 cubic feet.

MEMBER BANERJEE: Oh, so it's quite large. Okay. Because normally people take credit for mixing in the lower plenum area. Why is it that you can get away with it, without taking credit for it?

MS. GERKEN: Because we're not reaching the solubility limit before hot leg injection is initiated.

MEMBER BANERJEE: Well, yes.

MR. ROWE: Because the enriched boron layer, the amount of enrichment or the isotope that's used.

MS. GERKEN: It could be the 37 percent enriched boron. They're injecting at higher concentrations than we are.

MEMBER BANERJEE: All right. So given reasonable assumptions, quite a bit of margin, other than debris. But that's another story. Okay.

MR. SALM: This is Bob Salm again. Dr. Banerjee, I mean --

MEMBER BANERJEE: This is early, yes.

MR. SALM: Leave that up there. I mean the real significant conservatism -- put that curve back up.

MS. GERKEN: That one?

MR. SALM: That one, is that as time goes on, you're reducing the void fraction in the core considerably. It's, you know, filling up with liquid, and that increases the time that you have to reach the solubility limit considerably, I mean, if you were out at three and a half hours or something. So the one and three-quarter hours is a very, very conservative calculation.

MEMBER BANERJEE: Okay. That's a good reason, yes. Okay.

DR. SLOAN: That concludes that. I guess, Bob, I'm going to look at you. Did you want to go ahead and address the power measurement uncertainty question? Then I think that will wrap it up for AREVA.

MEMBER BANERJEE: My favorite subject.

MS. SCHOR: There was another one.

DR. SLOAN: What's that?

MR. TESFAYE: Control rod ejection.

MS. SCHOR: Control rod ejection.

DR. SLOAN: Oh, okay.

MR. SALM: They need to go with that.

DR. SLOAN: Okay. Would you want to -- okay. So let's do power measurement uncertainty, because that's quick, and then we'll move on to the control rod ejection.

MEMBER BANERJEE: I think we know your story, right? This is something new --?

CHAIRMAN POWERS: We're done with the Don and Lisa show?

MR. ROWE: The Don and Lisa show are complete.

(Simultaneously speaking.)

CHAIRMAN POWERS: Well, thank you very much.

MR. SALM: Again, this is Bob Salm from AREVA. I have to switch glasses.

CHAIRMAN POWERS: He can't talk with the right kind of or the wrong kind of glasses on?

MR. SALM: I'm getting old.

(Laughter.)

MEMBER BANERJEE: You know all that. Don't worry about that.

(Laughter.)

CHAIRMAN POWERS: And a great deal of

empathy over here.

MR. SALM: Okay. Cameron is the manufacturer of the Caldon Ultrasonic Flow Meter that the EPR is using, and they offered to come here, and they put together a really great one hour plus presentation on their flow meter and the testing that they've done to demonstrate that it is highly accurate. We looked at that presentation, said that's really great, but this is our presentation.

So what we asked them to do is give us a statement that we could read, and so I'd like to just read this statement from Cameron into the record. Okay. "Cameron has manufactured the Caldon Leading Edge Chordal Ultrasonic Flow Meter, LEFM, used by 60 nuclear power plants to perform highly accurate feed water flow measurements.

"The National Metrological Institute of Japan has calibrated the LEFM against a traceable standard for a variety of hydrologic geometrics and Reynolds number, that range from 1.10^6, typical for a calibration facility, to 2×10^7, typical for feedwater applications. For all configurations and Reynolds numbers, uncertainty remains within the plus or minute 0.2 percent band.

"This uncertainty betters the feedwater

flow measurement accuracy used by AREVA, 0.28 percent, to obtain an overall power measurement uncertainty of 0.48 percent. Cameron would welcome an opportunity to present this and other confirmatory data to the ACRS, and respond to its questions." That's the end.

MEMBER BANERJEE: So you know we have been around this a number of times.

MR. SALM: Yes.

MEMBER BANERJEE: The staff SE on this calls for certain things to be met. A couple of these have to do with vibration in a system. Well, I forget the details, but either in a system which is of the same geometry, or in situ. But after it is installed, there has to be some in situ calibration.

Now of course it can't be by direct method -- I don't have the document with me, but I guess every applicant is having to be very careful to fulfill the requirements of that SE, to allow the level of uncertainty you're talking about, you know.

Essentially, it is that calibration in external facilities cannot simulate the Reynolds numbers that you would get in the feedwater systems, because usually they're much lower. So even if you do ex situ calibrations, they are necessarily, at least have been in the past unnecessarily, at least the facility is not, have a much lower Reynolds number.

So there's a requirement in the staff SE to do some in situ calibrations, to validate whatever. One would have to read the fine print very carefully, to do it right. But it can be done, obviously, and I'm not quite sure what, how we dealt with it, because this has arisen with a number of applications. So we have some standard that is somewhere. Now it might proprietary information, I don't know.

MR. SALM: Well, the people from Cameron would really welcome a chance to come and talk with the ACRS.

DR. SLOAN: And maybe it's a separate, I mean not associated with somebody's docket, but maybe a separate briefing for your information, if you're interested in seeing the data that they have.

MEMBER BANERJEE: Right, if there's new data. But the staff would have to, you know, take a look or something first, because they're the ones who are putting this forward, right, to us. The thing that has happened is there was, if you look back in history, a lot of charges, counter-charges traded between various vendors and so on.

So the situation is fairly murky, and I just don't have total recall of what happened. We don't really want to get into this right now.

DR. SLOAN: Okay.

MEMBER BANERJEE: Other than the staff or an SE, and we just want to make sure that you conform to the letter of that SE, because we are concerned about the whole claims of accuracy. So but as long as you do what the staff has said, it's okay.

DR. SLOAN: Okay, all right. Dick Deveney, do you want to come address the control rod ejection questions? You can just introduce yourself.

MR. DEVENEY: My name's Richard Deveney. I go by Dick. My background is I have a B.S. in Physics and a Master's in Nuclear Engineering. I've been with AREVA and its predecessor companies for 34 years. I've worked in the Neutronic Methods Group that whole time, working with applications, code development and method development. I was the primary author of the ejector rod methodology report.

There were -- at the previous ACRS meeting, there were several topics, where additional information was requested, and I was going to provide some additional information on those issues. The first one was discuss the under-prediction of the integrated power, the SPERT3E Test 86 results relative to the conservatisms and uncertainties in methods.

Integrated power is important, relative to the prediction of the posited enthalpy limit in SRP 42. The integrated power of a super-critical pulse was tested, with numerous tests with SPERT3E. RIA events for current commercial PWRs only approach, prompt critical at core powers close to zero percent.

Therefore, the ability of the AREVA methods to calculate the deposit enthalpy is better represented by the Test 60 results from the zero power conditions. The calculated integrated power at the peak is 8.6 megawatt seconds. For Test 60 the measured is reported as 8.5 plus or minus 1.1 megawatts second, which is well within the measurement uncertainty for that test.

The testing question during the meeting, Test 86, presents some additional challenging conditions. As stated in the previous ACRS meeting, the SPERT core has fuel assemblies with different number of pins per assembly. NEMO-K has a limitation that all assemblies in the core have the same number of fuel pins, which is true for EPR and most other PWRs.

The resultant feedback for this case for Test 86 will be overestimated, and hence the integrated power is lower. A doubling time at hot full power -- another issue is that a doubling time at hot full power cannot be measured at full power. So that measured ejected rod worth uncertainty is larger than the uncertainty in Test 60. This fact is noted in the report, but no changes were quoted in any of the reported measured uncertainties.

As noted in the previous ACRS meeting, the predicted ejector rod worth was elevated to better match the measurements as was done by the NRC.

Thirdly, the definition provided for the integrated power contained more ambiguity for the Test 86 from full power. The report, IDO-12781 states that the integrated energy added is a net energy as a result of the pulse. This definition was interpreted by AREVA as subtracting the initial power from the pulse during the integration.

Using the SPERT 86 results to define the definition was inconclusive, because the error of digitizing the graph was similar to the result differences with the two definitions. AREVA reported a value of 13.7 megawatt seconds by this measurement definition.

If one performs an absolute integration, the megawatt second response for the AREVA calculation is 15.8 megawatt seconds, which is within the experimental uncertainty of plus or minus two megawatt seconds. The NRC staff indicated in a phone call that they used the absolute energy addition definition and an NRC reported value of 16.5 megawatt seconds, which is comparable to the AREVA reported values.

Based on these arguments, AREVA concludes that the method prediction of integrated energy is adequate. The uncertainties, biases and allowances made during the control rod ejection analysis are outlined in the rod ejection methodology topical report, NP-10286P. There is discussion in Section 4 and 7 on the uncertainties. The uncertainty of the calculated results is simulated directly with a biasing of the key input parameters.

The next topic was what is the basis for the clad temperature limit in the methodology? There are four coolability limits in the SRP-42 Appendix B. The clad temperature limit was created to satisfy one of the four coolability requirements from the SRP-42 Appendix B.

It reads, Item 4, "No loss of coolable geometry due to fuel pellet and cladding fragmentation and dispersal, and (2), fuel rod ballooning." This requirement presents several challenges to the applicant. The intent of this requirement is for the applicant to address the energetic response of the coolant and the physical structures to the direct exposure to the fuel, when the cladding is breached and demonstrate that there is no loss of coolable geometry.

AREVA chose to use a conservative approach to limit the cladding temperature, to preclude ballooning failures to meet this coolability geometry requirement of SRP-42. This approach avoids defining complicated geometric scenarios and calculations involving fuel to coolant energy dispersion.

If AREVA is able to show that there are no ballooning failures predicted, then there is no fuel pellet dispersal into the coolant. Since there is no fuel dispersal into the coolant, there is no need to define the relationship between the amount of fuel dispersal and acceptable coolable geometry, and thus the intent of the SRP is met.

Therefore, the meaning of this limit is more of a threshold of when dispersal calculations are required, rather than a hard temperature limit. To avoid balloon failures in subsequent undefined coolability evaluations, a clad temperature limit was defined. Two approved topical reports on M5 cladding material, BAW 10227 PA and BAW 10240 PA contain information that can be used to define a temperature limit.

In these reports, there are test results that provide the ruptured temperature as a function of stress on the clad at different heating rates. This is a straightforward calculation of the ruptured temperature, based on the strain rate from the pressure differential across the cladding wall, and the rate of change of cladding temperature.

Using the cladding temperature rate of change and the bounding high initial internal gas pressure discharge burnups, and low system pressure at the low pressurized or pressure reactor trip set point, a rupture temperature is obtained. This value is rounded down to the limit used.

This limit is very conservative, since most pins in DNB are low burnup pins that do not have an internal pressures higher than system pressure, and would not have balloon-type failures.

The third item was to provide additional details on the constant gap thermal connectivity model. The thermal mechanical interactions between the fuel and clad are recognized as being very complex during a reactivity insertion accident. The purpose of the integral testing of actual power excursions is used to formulate calorie per gram limits for the fuel to address these complex effects, relative to failure and energetic deposition of fuel into the coolant. These limits are clearly defined in the SRP-42 Appendix B.

The purpose of the constant gap with variable gap conductances for the fuel rod model in the thermal hydraulic code is to get a reasonable temperature response to the clad and fuel pellet during an RIA. A similar model is used in NEMO-K neutronics code, to determine the coolant and fuel temperature in a coarse or nodal model.

The constant gap with variable gap conductances model allows the geometry of the fuel rods in the water channels to remain fixed, while the thermal performance is allowed to mimic the thermal response of a fuel rod with variable geometry. This approximation allows significantly less complex model, resulting in less development and better run times. Code to code benchmark tests of this model were performed and presented in the topical report.

The response of the fuel to different gap conductances is represented by running both low and high burn-up fuel, which has low and high gap conductances, respectively. The worse result of the two conditions is reported.

The last item was to provide a discussion of the occurrence and DNBR early in the transient, and this was relative to the BOC hot full power condition. The rapid decrease in DNBR to the DNB threshold is due to many effects for the hot full power BOC ejector rod simulation.

The key reasons are (a), the initial fuel run F delta H, was conservatively set to the technical specification LCO limit. The resultant hot channel initial conditions for this case had a quality of seven percent, and a steam void fraction of 30 percent at the channel exit.

The neutronics power history includes a total core power change and an F delta H change, and an axial shape change, FC, due to the ejected rod. The rod is ejected at .1 seconds, so that the core power, the local F delta H and the local axial peak increased to their peak values, and remained relatively constant after the ejection.

The total peaking change in the top of the core where the rod was ejected results in peaking changes in excess of 45 percent. 35 percent was in the channel, which also includes core power, and also more than ten percent local, depending on where in the axial heights we're looking at.

The last important aspect of the DNBR change was that the minimum DNBR location quickly shifts to the top of the core from a center location, due to both the increase in total power in the channel, and the axial peak shift. The ejected rod from the top of the core shifted the minimum DNBR from a location that was sub-cooled, to a location that has roughly a four percent quality or 20 percent voids right after the initiation of event.

So to summarize this in what condition resulted, at one second, the heat flux in the peak channel is approximately 44 percent of the total step change in the neutron power, which illustrated a lag between the thermal and neutron powers expected. Are there any questions?

(No response.)

CHAIRMAN POWERS: I see none.

DR. SLOAN: Okay. That concludes our remarks and presentations.

CHAIRMAN POWERS: You're done?

DR. SLOAN: I hope so.

CHAIRMAN POWERS: And you're done?

MR. TESFAYE: No, we're not.

CHAIRMAN POWERS: You're not.

MR. TESFAYE: We have a presentation.

CHAIRMAN POWERS: That's right. You have a presentation. Ahh. Okay. Can we take a break now? We're scheduled to in 15 minutes.

DR. SLOAN: Okay.

CHAIRMAN POWERS: So why don't we take a break now, and we will come back at 17 after the hour. Roughly.

(Whereupon, the above-entitled matter went off the record at 3:01 p.m. and resumed at 3:16 p.m.)

CHAIRMAN POWERS: Let's come back into session I didn't care whether you were ready to go.

MR. TESFAYE: Actually, before we get started with the formal presentation of 15, Group 2, we'd like to answer the staff's portion of the rod ejection review.

CHAIRMAN POWERS: Ahh, yes.

MR. TESFAYE: So that's why we have Chris Van Wert here. Chris, please, go ahead.

MR. VAN WERT: My name is Chris Van Wert, and I'm an engineer with the Reactor Systems Branch and have been here for about four years now. Before that, I was with Westinghouse as a fuel rod designer, with Combustion Engineering as a programmer before that.

So as was mentioned, I'm here to answer the one remaining question the staff had regarding -- I'm sorry, the ACRS had for the staff regarding the rod injection review, and that was in the staff's confirmatory runs, what was the thermal conductivity used, and the answer was simply that it was the default value within TRACE.

So unfortunately, the engineer who did that wasn't here at the time, so he wasn't able to answer. So we wanted to make sure and come back and tell you, that you know, the actual --

CHAIRMAN POWERS: Okay. So you just used the default value in TRACE?

MR. VAN WERT: Right.

CHAIRMAN POWERS: Okay.

MR. VAN WERT: So with that --

MR. TESFAYE: Is that -- thank you. Thank you, Chris.

MR. VAN WERT: Thank you.

MR. TESFAYE: And Jess and Fred.

CHAIRMAN POWERS: You okay?

MEMBER BANERJEE: Yes.

MR. VAN WERT: Do I still owe you five bucks for Bud Lite?

CHAIRMAN POWERS: Whoa, I think I need to get in on this somehow.

MR. TESFAYE: Jason, please go ahead.

MR. CARNEAL: With that, we'll move into the formal presentation we have prepared today. My name is Jason Carneal. I received a Bachelor's and Master's in Engineering in Science and Mechanics at Virginia Tech in 2001 and 2004. After that, I worked at the Naval Surface Warfare Center Carderock Division for four years as a mechanical engineer, performing hydrodynamic experimentation on advanced hull forms.

Subsequently, I came to the NRC and since coming here, I've been working as a project manager in the EPR Projects Branch, covering primarily Chapters 4, 6 and 15. Today's presentation will cover the staff's safety evaluation report, Phase 2 for Chapter 15, Group 2, Transient and Accident Analysis.

Group 2 consists of Section 15.6.5. The remainder of the chapter was covered in an earlier group. There are exceptions, which I'll explain in a minute. The technical staff responsible for this review, Mr. Fred Forsaty is here. He's from the Reactor Systems, Nuclear Performance and Code Review Branch, and Getachew Tesfaye and myself served as project managers for this work.

Again, today's presentation will cover

Section 15.6.5. The caveat is that our Phase 2 safety evaluation report for Section 15.6.5 did not contain an evaluation of in-vessel downstream effects. This topic, as discussed before, will be delivered in Phase 4 design certification review. I would also like to note that we've issued a total of 113 questions in this section. When you exclude issue related to the in-vessel downstream effects, we have ten total open items remaining.

The next two slides give a general overview of the open items that are left in this portion of the review, that are grouped into three main categories: large break LOCA, small break LOCA and long-term cooling. I won't waste time going into the details of the questions that are outlined here, but these two slides given an overall generic overview of the outstanding concerns.

With that, I'll turn the presentation over to Fred Forsaty, who will go into the details of our review.

MR. FORSATY: My name is Fred Forsaty. I'm going to take about a minute and a half to give you a little background of what I have done the last 40 years, and then go cover the map presentation.

Hopefully, that will not be so long. I

started speaking broken English about 40 years ago at Kent State University. Then moved on after a year, went to Madison, Wisconsin. Got a Bachelor's in Chemical Engineering and then a Master's in Nuclear Engineering, worked with Mr. El-Wakil. I helped him to put that heat transfer book together.

After that, I went for a tour of different universities in California. I went to UCLA for a few weeks, Santa Barbara, Berkeley. Then followed Duderstadt to Michigan.

MEMBER BANERJEE: In Santa Barbara with my colleague, ex-colleague Theofanous?

MR. FORSATY: Yes. I was only there for a month or two. It was too rich for my blood, so I left. I ended up Penn State University. Spent seven years doing Ph.D. studies in Nuclear Fuel Management. I worked with Mr. Hofreiter, Levine and the rest of the group, Mr. Habib that was employed -- after my work at the university, my first job was at a small little company in Manhattan, New York, working with utilities like Westinghouse. After that, I went to --

CHAIRMAN POWERS: Let's see. Santa Barbara was too rich for your blood, but Manhattan wasn't. Let me see if I can understand this better.

MR. FORSATY: I can give you -- Santa

Barbara is a smaller town like Potomac, and everybody has the Potomac attitude. You drive with a -- I drove with a Firebird, a brand new Firebird in a gas station. They didn't want to pump gas in my car. They thought I'm not going to be a big tipper. So I had to go to another gas station that didn't have full service. But Penn State University is a very good school, you know. You're stuck in smaller town, and all you can do is study.

(Laughter.)

MR. FORSATY: Well, I thought it was good for that for a period, because I was a serious student.

CHAIRMAN POWERS: Studying at Santa Barbara is not high on the list. I know that.

MR. FORSATY: Well anyway, I ended up at -- after building a simulator for Arizona Power, I did the core and thermal hydraulics. I did one for 30 plants, and that took me about a year or so. Then I worked at the Maine Yankee Atomic. I see my old boss sitting here, I think. Then after I went to -- I went for a tour of different utilities at their hard times.

I went to Perry plant again. I went to Beaver Valley, Niagara Mohawk, ended up at the D.C. Cook. I spent five years there, helped them during the shutdown and bring it back. I was one of the NRC contacts working with Mike Rencheck that was the chief nuclear officer there. After that, in the year 2005, I decided to come back and live with my family that I only would see on the weekends. So I got opportunity to work with a good group of engineers.

Now having said all of that, I'm going to start from, I believe at page six, right? Yes, page six. Let me just give you a quick summary of what I'm going to discuss, to make everybody's life easy. I'm going to go through large break LOCA, small break LOCA and long-term cooling, and on large break LOCA, basically I'm going to give you a summary of the important issues we looked at, and on the small break LOCA, the same.

We have one or two open items, and then long-term cooling, I'm going to give you a brief discussion of what we had looked at and a summary of all the open items that we have on boron dilution, boron precipitation and long-term cooling, and then also we're going to conclude this whole session after we tell you, that we're not going to discuss downstream, which is going to happen later on in the next meeting with ACRS.

Going to page six, our 15.6, the study on large break LOCA is basically based on the ANP 102781, which is the large break LOCA topical report. Again, I know you had some questions about the, you know, realistic versus deterministic, you know, and that was a question that I had to really understand for myself. To the extent I understand it, I'm going to give you a two line summary.

This whole idea came across when we were trying to look at the power uprate done and we believe that we are taxing the vendors or the applicants on large break LOCA by going Appendix K. Then we put together, we went through the ASTRUM methodology, approved that, and basically that's a realistic methodology, to take a group of different variables.

We'd sit down with experts like Hofreiter. We'd pick 10-15 percent of the whole group of the variables that we think are the most important variables. We recall that chart. Then every single variable, then you go through the ASTRUM. We give it a realistic range. It has its own distribution, and it goes up and down the chart based on what we think or what the applicant thought is important -- question as to the extent possible.

What did we do? We looked at, for example, the way that AREVA was sampling the power.

We questioned that. We thought sampling power is not a good idea. So we asked AREVA to consider fixing the power at 100 percent plus the measurement of uncertainty, and they did that. We looked at the range of the variables that they are using, the accumulator and the RWST. I don't know if you still call that RWST.

But the range of the temperature that they were using was between 100, between 70 degree to about 120, I believe. We questioned the lower range because, you know, when you are 100 percent power, the containment temperature, therefore accumulated temperature and RWC should not be or could not be at 70 degrees.

So we asked them to go back and look at their operating plants, to come up with a more realistic range, and I think they came back and gave us a range of 100 degree Fahrenheit to 120. The impact on PCT, I believe it was within the range of 25 degree to 30 degree. So we did the best we could to make sure that the realistic methodology is really realistic.

At the times that we thought the realistic methodology should not be fully implemented like the power, we picked basically a fixed variable, and that

-- if I remember right, the changes are on top of what it was approved for the operating plant. Documents, I think it was 2103, did not have all these changes that we had made AREVA to incorporate in the EPR design.

CHAIRMAN POWERS: You are absolutely correct, that the methodology that they're taking in this non-parametric analysis, the key is that range that they select for each one of the parameters. That's where you could spend all your time on it, because I mean once you agree on the range, the rest is all mechanics. It's all well-founded mechanics.

The range, it does not matter what the distributions are. It does matter if they're correlated. That has an impact, and I think they probably have enough margin here that it doesn't, it's not going to change the conclusion. But the two things to focus on, the range, the ranges they pick, because people have a tendency to make those ranges very narrow, or in your case they're putting long tails down on the low side on them.

Then the second one is are the parameters correlated, because that, you know, you are sampling one high but the other one's low. You're kind of undoing the realistic effect.

MR. FORSATY: Well again, the way I convinced myself that if one is high, one is low, it's okay because you are allowing 124 cases to run, and then the whole idea is to be realistic. So you've got to let the system -- I know it cannot be a perfect system, but we do the best we can to make sure at least the realistic side of it --

CHAIRMAN POWERS: That would be okay on the averaging if you were looking at the mean.

MR. FORSATY: That's right.

CHAIRMAN POWERS: It's because you look at the tail, that you've got to worry about that correlation.

MR. FORSATY: I also would like to add that we reviewed the work that AREVA had done, working with Penn State on exactly your concern, and an extensive amount of work had been done, and we convinced ourselves that to the extent possible, the result is acceptable.

I'd like to also add a couple of more things is one, we asked AREVA to do 124 cases. We rejected the 59 case, based on the three variables, the acceptance criterias that are part of our rules and regulations. Then also I think also you've got to start thinking about the fact that in future, the realistic methodology most likely going to come to not only large break LOCA; it's going to be the whole small and large and then that's coming next.

CHAIRMAN POWERS: Yes. 124 cases is a pretty common number for people to grab. It gives you, what is it, I'm operating from memory. But I think it's a 99 percent confidence that you've sampled 95 percent of the potential range. It's something like that.

MR. FORSATY: I think that's correct.

CHAIRMAN POWERS: And I think -- and that's usually a pretty good range to sample. The essential point is you don't need 10,000 or 50,000. Somewhere around 100, 124 or something like that is pretty good, a good sample.

MR. FORSATY: And also it's very interesting to know that some countries will not consider large break LOCA as a design basis accident. Russians don't do that; they only do a small break. Going to page seven, I think we basically discussed all of this during our talk, and on page eight, we have listed the regulatory guidelines. This list is going to be repeated for small break and then for long-term cooling, we would add one more regulation or guideline to this list.

You have seen this before, GDC-13, that requires instrumentation to monitor the variables. GDC-35, which relates to ECCS, that would provide adequate cooling, and then 50.46, that would require the utilities to come back every year or so to update us on issues related to ECCS equipment, and the manner they handle the LOCA.

I'm going to go through the next two, three pages quickly, because we already talked about initial power. AREVA was using fixed, they were sampling initially plus or minus 22 megawatt, on top of the 100 percent. We asked them to go change that, their analysis, their design basis to 100 percent, plus the uncertainty, which I think, believe is like 0.53, in that range. If they exceed that, then they've got to go back to either do the analysis or take back some of the margin on the top.

Fuel temperature initialization. Again, we inherited this. The whole analysis of large break LOCA topical was based on the operating plant analysis, which is, I believe is Document 2103. Once we inherited that calculation or that analysis, we looked at the thermal conductivity and how it was calculated. We realized that the thermal connectivity degradation, as a function of burnup was not properly modeled, or the Halden data actually.

The latest Halden data was not a part of the RODEX3A. We went back to AREVA or RODEX4, and I think that RODEX4 was updated. Now is using the latest Halden data, and once they made the changes, the impact on PCT, I believe, was about 50, 55 degrees.

We only have one open item. That's a pointer. It's this 15.65 large break LOCA analysis. FSAR points at that topical report review, which Jason is in the process of finalizing that, and once it's finalized, we will close this RAI.

So the conclusion is that I think based on the feedback we got from ACRS when we brought the topical report safety evaluation, they did an adequate job, and probably more than adequate, and we believe that the work that had been done is acceptable at this point for the large break LOCA side of it, as opposed to the FSAR is acceptable. So AREVA had followed the rules and regulations applicable to large break LOCA.

On the small break LOCA, small break LOCA initially, the initial review was done prior to us inheriting the work. We looked at it carefully and we had some questions on top of the ACRS question, and basically RODEX, the small break LOCA is using two computer codes, using SRELAP, which is the same as -- SRELAP5, which is the same code as AREVA is using for large break LOCA. On top of it, they're using RODEX2A.

RODEX has different versions, RODEX 2, RODEX2, RODEX3, RODEX4, RODEX2A, 2, 2A. But they're all basically doing the same kind of work, except there are different version and the intent at some point, the way I understand it, some of these revisions are put together specifically for one type of plant, for PWR or BWR. But the basic coding are very similar.

So they're using RODEX2A for this analysis, and in combination with SRELAP, RODEX2A basically calculates the initial condition, the fuel temperature and stored energy, and SRELAP takes over, runs the small break LOCA and they have a small baby RODEX in the LOCA analysis, SRELAP, that updates the thermal conductivity as a function of burnup, so they can go from Point A to Point B during their analysis. They do the same thing for the large break LOCA.

Any questions on the small break? We're going to come to the next page. Reg Guides are the same as the large break LOCA. I'm not going to go through that. Page 14, we have an open item and then also I was, I think I was told that a question was asked regarding the condensable gases on small break LOCA.

I just would like to touch base on that, give you as much of the information I have, and then talk about the open item we have on the small break LOCA. On the condensable gases, I went back and we have asked a couple of questions. One is Question No. 5. Basically on this question, we are setting the tone for asking additional questions on non-condensable.

We basically have asked AREVA to show us that SRELAP basically models the small break LOCA properly. Do you have any tests that support that? They came back and they showed us the BETHSY test that had been done, and basically the result shows sufficient response, which shows similarity between the small break LOCA analysis and BETHSY -- but however, I'd like to point out that the BETHSY, the way I understand it, I don't remember that they had used any non-condensable gases in their tests. But without the non-condensable, it appears that the result shows that the SRELAP, as it models small break LOCA, does an adequate job.

CHAIRMAN POWERS: They used, for their

critical flow calculations, they used the ideal gas approximations. Then they had nitrogen and steam together. That a little bit surprised me. I mean I don't know that it's wrong, but I would not have thought that you could get good results doing that with steam at those kinds of temperatures.

MR. FORSATY: Well, I agree with you, and we basically asked a question into that effect. That's Question No. 23. Is that right, Question 23?

MR. CARNEAL: The question he's referring to is in RAI Set No. 30, Question 15.6.5-23, which can -- the response to which can be found in ADAMS NL 08274037.

(Laughter.)

CHAIRMAN POWERS: If you can find something in ADAMS, then I hand it in to you. I can't.

MR. FORSATY: Thank you, good job.

MR. CARNEAL: That's the number.

MR. FORSATY: Yes. Anytime I need help, I go to Jason.

MR. TESFAYE: We can get a copy of this response to you.

MEMBER BANERJEE: Shack can.

CHAIRMAN POWERS: Yes. Shack can, but I

can't.

MR. CARNEAL: This response contains the sensitivity study that AREVA alluded to previously in their presentation.

MR. FORSATY: I think there are a few good things here that we'd like to share with you. One is that the way I understand it, and I think is accurate, that once the non-condensable gases are detected, the accumulator flow will be stopped. So you've got the non-condensable gases right on top of the accumulator. So I think there is some kind of gadget that reads it, the flow, and it knows how much water is in the tank.

Once it detects the non-condensable gases, I don't know the exact procedure. But I know that is a design basis. So hopefully non-condensable gases would not go to the core. Now we had the same issue for large break LOCA. We asked question, extensive questions on non-condensable gases, its impact on PCT and other issues.

AREVA, I think, they did an extensive work-through to convince us. One is that the condensable gases would not come in until maximum PCT is reached, which now you have further question. It's not only the impact on PCT, the impact on everything else when it comes to the small break LOCA. Does it go to steam generator? What happens to all these non-condensable gases?

So that's Question 23, and again, one more thing I'd like to add here is that SRELAP uses Moody's Homogenous Equilibrium Model or HEM model, right, when it comes to calculating the critical flow. Now we did some work at that time, to make sure we understand this. I went back to my notes, and basically the HEM model is calculated or is modeled, is a simplification of the Moody's critical flow model.

You put the slip ratio equal to one. So that way, you're basically simplifying the process and you would have basically equal phase velocities, right. All right. Now we did a little bit more research on that, and then we looked at the HEM model, which we believe or still we believe that is good for high pressure long types.

We did some research, and I have a copy of the work that we looked at, and I can give it to you at the end of this. It showed that the HEM model predictions are better than Foskey's correlation. So that's one thing. And then, on top of that, we went back in Question 23. We asked them to show us what happens to these non-condensable gases.

AREVA came back with a whole group of

sensitivity runs, which I have it here, and the sensitivity runs basically shows that the non-condensable gases would go through the system, through the core, and get out of the break in a timely manner, and would not end up as steam generators.

MEMBER BANERJEE: How did they show that? That's really, you know, why wouldn't it separate and sit at the top?

MR. FORSATY: Again, that's a good question. We don't have no test results to show that. We can only look at the analysis. We look at, you know, their small break LOCA model, which had been basically benchmarked based on PKL tests without the nitrogen, or without the non-condensables.

Then again, I agree with you, there is -- there are no guarantees that some of the non-condensable gases would not show up somewhere else. But we convinced ourselves that most of the non-condensable gases would find its way out through the --

MEMBER BANERJEE: I think it depends on the flow regime. If in the steam generator tube you have a fairly well-mixed flow regime, you know, then that's a reasonable thing to happen, because the non-condensables are mixed with the steam.

MR. FORSATY: That's right.

MEMBER BANERJEE: But if you've got something where the flow sort of separates quite a bit periodically, a little bit could be left over, not easily entrained.

CHAIRMAN POWERS: But not nitrogen, because nitrogen is denser than steam. So it's not going to separate out for you.

MEMBER BANERJEE: Not separate out. Yes, that should be some good argument, or based on an experiment or something, that this flows. Or maybe not.

CHAIRMAN POWERS: I mean you just wouldn't expect nitrogen to separate, because it's denser than the steam.

MEMBER BANERJEE: It will just stay there.

CHAIRMAN POWERS: So it's never going to go up. It's always going to come down.

MR. FORSATY: But again, each of these analyses are really, you know, a lot of information is out there, and you can only --

MEMBER BANERJEE: So this is a natural circulation, right, in this regime? So if it starts to, you know, if the velocity goes low in one place, you'd probably get both the steam and nitrogen separating out to begin with from the water. I mean nitrogen probably will not separate from the steam.

CHAIRMAN POWERS: I mean the dynamics of solubility in this are very complicated --

MR. FORSATY: And also we have --

CHAIRMAN POWERS: --because of the behavior of gas solubility.

(Simultaneous speaking.)

MR. FORSATY: Again, we think it's reasonable, and the follow-up question on that basically also would help, would allow AREVA to maybe provide us with more information to satisfy the staff that that non-condensable gases will leave the break. The next question is basically we had asked the applicant to provide validation of SRELAP, to model the countercurrent flow.

That's an open item, and AREVA will come back to us with hopefully sufficient information to close this question.

MEMBER BANERJEE: Is the steam generator at any point, it's already acting as a heat source here, isn't it, as -- heat sink? Is the steam generator acting at all as a heat sink, this part of the transient, after the non-condensables --

MR. NITHIANANDAN: Well, that's not --

heat source --

MEMBER BANERJEE: That's what I'm saying, yes. It's a heat source.

MR. NITHIANANDAN: Yes, because you're pressurized higher --

(Simultaneous speaking.)

MEMBER BANERJEE: It's a heat source.

MR. NITHIANANDAN: It's a heat source, yes.

MS. SCHOR: It's a definitely a heat source, and you see the difference in guidance, is that in our analysis, we start injecting condensable for -- start with a 7.5 inch break, and PCT for that case alters at about 300 seconds. So we turn around and we start injecting non-condensable from the break at 800 seconds. So that is when we assume accumulator isolated, and we run it for 1,000 seconds.

So we all the breaks from seven and a half to ten percent, including accumulators, line break, isolate the accumulator. We run some of those -- those are the bigger breaks. So for those breaks, you have enough flow to the breaks, so that the non-condensable get entrained around the annulus to the break.

We plot it, everything. The core, the

upper plenums, the tubes, and we presented to that the Commission in our responses, and at least the code didn't calculate that the nitrogen was entrained at the upper elevations.

MR. NITHIANANDAN: The downcomer, the lower downcomer is full of water. So there's no air can go down, and the flow is positive. So there's no way the flow can go into the generator. So the flow has to go -- physically, there's no mechanism for the nitrogen to go into the tubes, because the downcomer to the lower plenum is all filled with water.

So there is very little evidence that the flow, particularly the larger breaks, the flow it appears to be will be most of the time positive.

MEMBER BANERJEE: I actually don't see a mechanism to de-entrain in the area.

MR. CARNEAL: Yes, no.

MEMBER BANERJEE: Well, I'm fine. I brought it already, but I have to ask it.

MR. FORSATY: Okay, next page please. Here, the conclusion that the staff has is that except the open item that we discussed just a couple of minutes ago, we conclude that the applicable rules and regulations and the guidelines are satisfied with respect to the small break LOCA as of today.

The next page. Okay, that's the last segment of our presentation. Here, we're going to discuss post-LOCA and touch base on other open items on that, boron dilution, boron precipitation. Here, basically the whole idea of the review here is to basically to ensure that the decay heat has been removed or will be removed, and the boron and debris would not impact the long-term cooling. That's the basic reasoning for the review here.

The Reg Guides, we have discussed them before, is similar to large break LOCA or small break LOCA, and again, the last bullet basically ensures that the decay heat is removed from an extended period of time. Now the next few slides, we're going to quickly go through the open items. These are all open items, and in most cases, we are doing the best we can to ensure that AREVA would address the uncertainty versus the conservatism that's needed, to close the loop on these issues.

We're looking at the mixtures, mixture volume, how much of clean water slugs do they have, how they're generated, what they're seeing and how they go to core, how much of it go to core, and what kind of impact it would have on the criticality. Question No. 61 in here, we're basically asking how much clean water is generated during the reflux condensation, where does it go, and how this amount of slug would impact the boron dilution. It's a very simple question, but then the response is going to require quite a good amount of work.

We have had this discussion with AREVA before in a public meeting. I believe it was July 15th, 2010. Question No. 62. Here, we are asking the applicant to show that if this diluted slug water that we're talking about in 61 ends up in the core, what's the impact on criticality and the consequences of that?

Next page. Question 63 is a dilution, boron dilution question, and we are asking the applicant to present experimental data to justify the design basis or the long-term cooling and the dilution part of their analysis. We're looking for experimental data on boron dilution.

Question 70 is on long-term cooling. If you remember when they had a discussion on long-term cooling, they had a cartoon here that had different paths. Path one that goes to, that connects, that shows the connection in the downcomer. They have 32 nozzles on the downcomer within the core barrel and the vessel.

That's a design. That's an EPR design that's different from other designs. We asked a question on that bypass, to get more information on the flow area and the flow resistance to better understand that. So that question is on that.

Next page, please. Question 99 is on precipitation. Here again, we are going back to future. We are connecting precipitation to downstream. We are asking if there is a core blockage, how that's going to impact the boron precipitation during hot leg injection or cold leg injection. Let's assume that there is some kind of core blockage, and then you have borated water being injected.

Then you have steam that boron-free is moving out of the core, and how this process would be impacted if you have core blockage. So that's a basic, simple question. Here, what we're trying to determine, if we -- how much of an impact it has reaching, to show that the precipitation is below the limit of, I think, I believe it's 38,000 PPM.

Next page. This question is basically in my mind, is not as important as when we formulated it. Here, we're asking question is what's the impact of the amount of debris that accumulates on the spacer grids or in the core during the downstream, and how much of impact is that on the volumes of water and impact on boron concentration.

But then we get the audits. It was very clear to us, again in my mind, the impact should not be significant.

MEMBER BANERJEE: No. There's going to be not that much debris.

MR. FORSATY: No, it's not in there.

MEMBER BANERJEE: It will have a different effect. It can block the flow in the core; correct?

MR. FORSATY: But for a person like me, I'm green at the agency. I didn't know anything about GSR-191, and -- I was still green. But then I'm not as green. So we're still going to wait for AREVA to give us feedback, and then we would look at that.

Question No. 66. Here, basically the question again is very simple. We are asking that you have hot leg injection. You have a steam which does not have any boron going from core to the steam generator, and then you've got some water coming. You've got hot leg injection water with boron trying to go to the core. Is the steam going to prevent or impede the safety injection flow through the core, reaching the core?

That's basically the basis for that question. I think that somehow they're using Wallis correlation here, if I remember right. So we're questioning that.

Next, then it goes to my favorite section, Conclusions. 68 is precipitating question. Here again, we've got safety injection, which is borated water comes into the core, which hopefully will match the boil-off rate, and then you've got the core steam that is leaving with that. It's boron-free water, and then basically the precipitation is riding on this too, one leaving. Deborated water or clean water leaving, and safety injection bringing boron.

So we're trying to understand how all these things would work together to show that there is no precipitation. Again, this is generated, the question. I think this question had been somehow incorporated in other questions. But then this had been formulated to basically understand the precipitation a little bit better.

I'm going to go through conclusions. Then, if you have any questions, we can discuss it. Again, we looked at the large break LOCA, which points at the topical report, which is almost approved. We looked at the boron dilution. AREVA did not discuss boron dilution. We have some open items on boron dilution.

We discuss boron precipitation, and we have a lot of RAIs, and some of these RAIs points to downstream, which we do not have their final test results. But I believe that in the next few months, their application is going to be finalized. We're going to look at the downstream application, and hopefully as part of that, we should be able to close some of these RAIs going forward.

I think my boss is happy I'm finished, and if you don't have any further questions.

CHAIRMAN POWERS: Any questions on this?

MR. TESFAYE: Well, that's our presentation, Dr. Powers.

CHAIRMAN POWERS: We have one more section on 15 to go through.

MR. TESFAYE: Yes. That's the --

CHAIRMAN POWERS: No, I mean --

MR. TESFAYE: Oh oh, here?

CHAIRMAN POWERS: In the future we have still issues to go through --

MR. TESFAYE: Not in Phase 2, Dr. Powers. That will be in Phase 5.

CHAIRMAN POWERS: Five, okay.

MR. TESFAYE: Yes, for GSR-191.

CHAIRMAN POWERS: Okay. So you're moving all this stuff into four, and we'll see it in five?

MR. TESFAYE: Yes, that's correct.

CHAIRMAN POWERS: Okay.

MR. TESFAYE: This completes the Phase 3 presentation of Chapter 15.

CHAIRMAN POWERS: Okay. So we need to do, decide when we'll come to a full Committee, so we can move these things forward. You can work with Derek and we can work that out in some way. But I think we're ready to move on 15, aren't we, that part that we've seen?

MR. COLACCINO: Yes, yes, we absolutely are.

MEMBER BANERJEE: So just to clarify, the items which are with open items, they'll be considered under Phase 4 or 5?

CHAIRMAN POWERS: That's right. We're trying to do this in a phased fashion, just to get -- so it moves right along, and we don't get hung up on an issue. But if we had burning issues that are really orthogonal, we want to hear about them now. But I don't see any of those in 15.

MEMBER BANERJEE: Are we going to write a letter at some point, an intermediate letter Dana?

CHAIRMAN POWERS: We've done that episodically. We have two of them up now, and so now we just have to do a third one, and it's going to be a little bit different, because it's going to say look, some of these things we moved into a future phase.

So we'll, instead of saying something that says like we don't find any issues to preclude certification, it will say "we look forward to continuing to hear about these issues," or something nice and innocuous, because I don't --

MEMBER BANERJEE: So we're not going to wait until we close all the open items?

CHAIRMAN POWERS: Nothing, we're not going to wait until we close all the open items, that's right. I don't see anything where I would say we're at real loggerheads, do you? I mean I don't, in 15. It's just a matter of going through it right now. So I think we can talk about doing a presentation to the full Committee and moving these forward on this.

MR. TESFAYE: Yes. We have a few chapters that we have completed since the last full Committee.

CHAIRMAN POWERS: Yes. So we can --

MR. COLACCINO: Dr. Powers, it's Joe

Colaccino. The only question I have is do you want to wait until we bring the rest of the chapters for Phase 2 before we have that full Committee meeting, or do you want to do a full Committee meeting --

CHAIRMAN POWERS: I am willing to do it in whatever way is most -- I don't want a big inventory to build up for a long time. But that's more for your scheduling and the applicant's scheduling than anything else.

MR. COLACCINO: So then we would defer to working with Derek, to get a -- to our presentation to the main Committee.

CHAIRMAN POWERS: Right now, breaking into the full Committee schedule tends to be an issue. So I'd say let's break in whenever we can.

MR. WIDMAYER: If you're planning on finishing in February, though, isn't that right?

MS. SCHOR: Yes.

MR. WIDMAYER: So potentially you could just have one.

MR. COLACCINO: And Derek, that's why I asked the question.

CHAIRMAN POWERS: Yes. Let's take a look at the Committee's schedule, because that tends to -- that's been tending to be pretty full, with Fukushima and things like that. But we can work that forward and what-not.

MR. COLACCINO: And with the pieces of the safety evaluation that are left to come, the topics that are left to come, represent a significant amount of work and documentation. There's a lot of material that's coming to us.

CHAIRMAN POWERS: It really might be worthwhile to go ahead and get this part out of the way, because we don't know what we're going to run into, especially with digital I&C and things like that coming down the pike.

MR. COLACCINO: Okay. Again, we will --

CHAIRMAN POWERS: We will work on those issues. Well, in that case --

MR. TESFAYE: Yes, we're done. Thank you, and I appreciate again for your flexibility to allow us to present I&C in November.

CHAIRMAN POWERS: Yes, yes. I think that's going to work out just fine. I don't think we've got a problem there, because I --

DR. SLOAN: Thank you.

CHAIRMAN POWERS: And thank you, Dr. Sloan, for finally showing up at one of our meetings.

MEMBER BANERJEE: Especially Chapter 15,

right?

CHAIRMAN POWERS: Again, I compliment everybody on their presentations. You guys really do, I mean both staff and applicants really do a great job on these presentations. I know they take a lot of work. I know the work shows. You're doing an excellent job, and it makes my life very easy when you have nice presentations like this.

DR. SLOAN: Thank you, Dr. Powers.

CHAIRMAN POWERS: Okay. We're now ready to move on. Arora's going to come in here. Hey stranger. It's been a while.

(Off mic comments.)

CHAIRMAN POWERS: I am ready, but my compatriot is not. I mean we've got two thermal hydraulicists here talking together, which is guaranteed to go on for a while. Surinder, you can go ahead and start.

MR. ARORA: Okay, sir. Good afternoon Mr. Chairman and members of the Committee. My name is Surinder Arora, and I'm the late project manager for Calvert Cliffs Unit 3 COL application. We are here to present Chapter 15 for Calvert Cliffs, and the way we will have this presentation, Dr. Powers, after my brief overview of the project, I will turn over the meeting to Mr. Gibson, and he will make the UniStar presentation, and then the staff will provide staff's presentation, a few slides.

CHAIRMAN POWERS: Is this is radical departure from previous?

MR. ARORA: No, it's not. It's not.

(Laughter.)

MR. ARORA: In the overview, the first slide I have here is a chronology of the application, how it was submitted, various revisions of the application, and without going through the past history, I'm going to stick with the present. We are currently at Revision 7, and that's the revision that has been used for this chapter.

As of today, this highlighted item here on the slide, we have completed SER with open item presentations to the ACRS Subcommittee for 11 full chapters and one partial chapter, and then out of these SERs are open items for nine full chapters and one partial chapter have also been reviewed by the full Committee, and the project has already received a letter from ACRS, indicating no significant issues on those chapters.

Next slide, please. This just indicates that Chapter 15 is being presented today to the

Subcommittee, and we plan to present two more chapters in the November Subcommittee meeting, and that's what we were shooting for right now, working on those chapters. Those will be Chapters 7 and 18, which are mostly IBR, just like this chapter.

So I don't think it will take too much time from the Committee. That's the people that work on the project. I don't want to take too much time. Are there any questions?

CHAIRMAN POWERS: The only comment I'll make. Work with Derek and we'll summarize and get a letter out on the chapters we've completed, just so we don't get a big backlog of things. It keeps everybody's bookkeeping happy, and we can -- I mean this kind of phased approach, I have to admit that I was very skeptical of it when we undertook it. But I think it's working well, in this particular case.

I mean it's just a testimony to the technical capabilities of everyone involved. But it's working well, and I think we ought to take advantage of it as best we can. If you work with Derek, we can set what gets covered and when and things like that, so that we get our -- keep our books straight here.

MR. ARORA: We appreciate your help with that. If there are no questions, then I'll turn over the meeting to Mr. Gibson.

CHAIRMAN POWERS: The Mr. Gibson show.

MR. GIBSON: Okay. It should be the second one down. There we go.

CHAIRMAN POWERS: Recognize those?

MR. GIBSON: Yes, I do. Yes, I do. Dr. Powers, again Greg Gibson, Senior Vice President of UniStar. I'm pleased again to be before the Commission, and good to see you, sir. What we'd like to do is to review Chapter 15, especially since we've just finished the design certification, and as you're aware, we utilize the incorporate by reference. So I'll skip basically my first slide there.

Today, I do have on the phone and available Tim Kirkham and John Hamawi, and Jerald Holm from AREVA, to help us with the presentation. But I think as you'll see, we're really where this was an IBR section. I say that, because we are going to talk about COL information items and single departure that we have.

With regard to our COL item, we only have one, and it's a very reasonable and prudent one. It talks about the transient analysis, and that what we need to do is provide the NRC a report in the future, which has again, the items that you see listed here.

I won't read them, and the four items that we would have to prepare in a report for the staff. It's a very standard report, and of course, we're pleased to do so. That's our only COL item.

CHAIRMAN POWERS: This really is not different from any core load?

MR. GIBSON: No. It isn't.

CHAIRMAN POWERS: Yes. So it's your core load report?

MR. GIBSON: That's it.

CHAIRMAN POWERS: You'd have to do this in any phase.

MR. GIBSON: Absolutely, although now it's a COLA.

CHAIRMAN POWERS: Yes.

MR. GIBSON: With regard to the departures, as you recall when we were here for Chapter 2.3, we talked about meteorology, and we did have the one site-specific chi over Q value, which was different than that which was provided in the design certification.

As a result of that, we did have to do some specific calculations for the reference call it, and for our site-specific factors to reflect that departure. So that was reflected also, not just in

Chapter 2.3 but in Chapter 15.

This is the table that we have, which basically shows the, everything as well within the dose limits. It was just really a very minor increase in the chi over Q values at the site area boundary and so forth. So with that, we had to reflect and cascade the one departure into Chapter 15.

Okay. That being said, our conclusions. One COL item, one departure. We have no FSAR open items or confirmatory letters items at this point. I'll of course turn it over to the staff, if they have anything additional that's come up on a potential item. We have no ASLB contentions related to these topics, and responses to all our RAIs have been submitted. Thank you.

CHAIRMAN POWERS: Good heavens. Do you have any questions for this exhaustive and detailed presentation?

(No response.)

CHAIRMAN POWERS: Your life is too easy, sir. Thank you.

MR. ARORA: That concludes UniStar's presentation, and we are ready with the staff. Please come here to make the staff's presentation.

CHAIRMAN POWERS: This is a ragged crew

you've got coming up here.

MR. ARORA: Jason Carneal is the project manager for Chapter 15 for Calvert as well. He has already been introduced.

CHAIRMAN POWERS: Yes, I don't know. We're going to have to check her credentials. I'm not too sure about this.

MR. ARORA: I'll then introduce the staff members.

MR. CARNEAL: To pick up where we left off, again, we'll be presenting our Phase 2 safety evaluation report for Calvert Chapter 15. As stated, most of this chapter was IBR, but there were a couple of sections that had site-specific information which required review by the staff. The review team included members from the Siting and Accident Consequence Branch, and Reactors Systems, Nuclear Performance and Code Review Branch.

Just a general overview. The only two sections that did contain site-specific information are Section 15.0 and 15.0.3. Again, the rest of the sections in Chapter 15 were completely IBR. I would note that we have zero open items in this chapter that are unique to this chapter. These totals do not include the reference to a generic open item, which we've created to track the DC review to completion. So I just wanted to make that distinction. In order to cover Section 15.0, I'll turn the presentation over to Shanlai Lu.

MR. LU: Shanlai Lu from the staff, Reactor Systems Branch. I only have two items to discuss, and the first one is the COL Information Item 15.0-1. Actually, we actually presented to the staff last year Phase 2 SER and back to February for non-LOCA section. This one was identified.

This is a particular item that came from the review of the set point methodology, a topical report and then we did have the limitation on that one, because the uncertainty analysis at that time by AREVA in the topic report was based on the assumed number. So when you have -- of course you have actual number.

So that's, the you know, natural question becomes if you do have an actual system built in, what's the uncertainty? What's the uncertainty with respect to uncompensated DNBR, and limit power density. So that's what we're asking the RCOL applicant to address this issue as part of COL information item.

They did do that, and in Chapter 15, they identified that specific item and then documented what's the, you know, what detailed plan needs to be done as part -- to address this COL item. So we compared whatever we noted as part of our SER in the design cert for Chapter 15, and also the topical report SER, and we found it's acceptable. So therefore, that's a simple issue as UniStar presented it.

So that's the first item. The second item, as I mentioned, it's -- I think UniStar has already mentioned. It's a potential new ITAAC on the COL information item, simply because we are still working through this item. It's not a show-stopper, definitely not a show-stopper at all, but it's related to the power measurement uncertainty, and I think early afternoon we talked about the power measurement uncertainty.

One of the items we identified through the design cert, and we audited the power measurement uncertainty calculation, and we found there are several assumptions related to the different -- for example, the pump power and then also feedwater inlet temperature pressure, all those sensors.

Right now, the uncertainty of those sensors and all those components at this point are assumed. So therefore, when you have a real plant being built, that may change. So that's another potential item coming in, for us to ask the licensee or applicant to address this possible ITAAC in the COL information item, regarding the power measurement uncertainty.

So that's, those are two items I want to cover. Any questions?

CHAIRMAN POWERS: There's nothing they can do about them until they actually have a plant.

MR. LU: Exactly. That's the whole point.

CHAIRMAN POWERS: And we need really to flag those things and take care of them when they come.

MR. LU: That's it.

MR. CARNEAL: Okay, and Michelle Hart will be covering the presentation for Section 15.03.

MS. HART: Yes. I'm Michelle Hart from the Siting and Accident Consequences Branch. I've been doing this for about 15 years all told, so take that as you will. The Chapter 15 analysis, what I had to review was whether they had appropriately incorporated by reference the EPR FSAR DBA and dose analysis. Much like we had discussed with Vogtle and with Summer, if the chi over Q's for the site are less than the chi over Q's used in the design certification review or in the analyses, excuse me, then therefore you had shown that the plant at that site is acceptable.

Calvert did have one exception. It was for a low population zone, chi over Q for the first two hours and 022 chi over Q. It was slightly above what was used in the FSAR. So they did site-specific dose analyses, and I did have one question, as you saw on the previous slide that Jason had, and that question was even though the dose, I mean the chi over Q went up, their doses went down, compared to the FSAR. So I had to ask why that was.

That response was well, they used all of the site-specific chi over Q's for each time period, not just for the first time period. So all over dose analyses did incorporate by reference the FSAR, and so therefore they've shown that they meet the regulations on this slide.

CHAIRMAN POWERS: When I look at their large break LOCA dose, it did sense below the limit. I mean everything's fine there, but it looks high to me for a large break LOCA. Do we know why?

MS. HART: Well, the chi over Q's may be maximized to help them put it on, you know, a larger range of sites.

CHAIRMAN POWERS: So maybe it's just conservatism in the way they did the calculation?

MS. HART: Right. Given that you incorporate a design calculation, which is maximized to allow it to live on several different sites, when you incorporate by reference for the specific site, you don't have the specific site dose reported. So it may be less, and in fact it would be less, except for at the LPZ.

CHAIRMAN POWERS: Yes. I'm used to doses three, four, and this one comes in at nine. I just, you know, why?

MS. HART: Yes. Well, that's not at the LPZ. If I remember correctly, the EAB is higher, of course.

CHAIRMAN POWERS: Yes.

MS. HART: I think that's a function of the design certification idea.

CHAIRMAN POWERS: It's just this conservatism that's built into it at this stage.

MS. HART: That's correct, that's correct.

CHAIRMAN POWERS: Yes. It just surprised me a little bit, because I mean this is a pretty robust containment, and I guess they don't ask for credit for sprays, do they?

MS. HART: In this particular one, they do not They did take a large --

CHAIRMAN POWERS: They don't love sprays, by the way. I guess when you think about it, if you don't have sprays, then you're sitting there with a lot of radioactivity in containment for a long time. So that gets you in trouble. I mean it doesn't get you in trouble. It just leads to a little higher dose.

MS. HART: And the leakage is still fairly high. They're use the tech spec leak rate for the first 24 hours, and then half of that for the remainder of the accident, 29-1/2 days.

CHAIRMAN POWERS: Okay. So that makes sense. Okay, okay.

MS. HART: Do I have another slide? I think I had another slide. But you know, it's the description of, you know, the site characteristic values are bounded. So it's that whole concept, which I've presented before. We did do, the staff, I did confirmatory analyses on the low populations on calculations, and I was able to verify, you know, that small increase in the 0 to 2 hour --

CHAIRMAN POWERS: Did you use RADTRAD to

do that, or --

MS. HART: I did use RADTRAD. Yes, that's correct, and I used the -- because I'm also the reviewer for the EPR FSAR, I used the analyses I had done to verify that. So I did it front to back. I didn't do a ratio or anything like that.

CHAIRMAN POWERS: Okay, thanks.

MS. HART: So we were able to show that they meet the regulations, either by incorporation by reference or by showing site-specific analysis.

CHAIRMAN POWERS: I like this, when the staff actually does their own calculations, using their own tools and can confirm in an independent fashion. That's good. That's really good. Well good.

MS. HART: Do you have any questions?

CHAIRMAN POWERS: Now why don't they love sprays the way I do?

(Laughter.)

MS. HART: I've mentioned it to them several times. I think you've done about all the convincing they can stand.

CHAIRMAN POWERS: Why don't you love sprays? They're so nice. They take care of things. They get through that nasty radioactivity. She's growling. If looks could kill right now --

MS. HART: They have their reasons.

CHAIRMAN POWERS: I just don't want to take -- they don't want to take care of another piece of safety-related equipment. That's the only reason.

DR. SLOAN: We have an elegant solution.

CHAIRMAN POWERS: An elegant solution. It gives me nine RAD, nine rem. Okay. Thank you very much. Again, we'll work with Derek. We can work out some of the mechanics on this. I think this is very straightforward for -- I mean the chapters we've done are very straightforward. So we ought to get that just banged out as quickly as we can.

MR. COLACCINO: Sure.

CHAIRMAN POWERS: Wherever we can dynamite ourselves into the schedule, we ought to do that.

MR. ARORA: I've talked to Derek.

CHAIRMAN POWERS: Yes. We can work with Derek on that, and because we have a bunch of chapters coming that are more difficult. We ought just get this quickly along.

MR. COLACCINO: We agree.

CHAIRMAN POWERS: Yes. I mean it just makes life easy for everybody concerned. Okay. Well

MR. ARORA: That concludes our Chapter 15 presentation then, Dr. Powers.

CHAIRMAN POWERS: Well, I'm sorry to put you through this honor.

MR. ARORA: I want to thank you for the opportunity --

CHAIRMAN POWERS: Yes, yes. Lie to me some more. Any other comments that the members of the Committee would like to make?

MEMBER BANERJEE: Great presentations.

CHAIRMAN POWERS: They really are very thorough. They really do nice presentations.

MEMBER BANERJEE: Or questions, compliments

CHAIRMAN POWERS: I mean that's true across the board, by the way. Really nice presentation, and getting to the point and things like that. At that point, I propose that we adjourn.

MEMBER BANERJEE: Bravo. I like that.

CHAIRMAN POWERS: We are adjourned.

(Whereupon, the above-entitled matter went off the record at 4:28 p.m.)

U.S.NRC

United States Nuclear Regulatory Commission

Protecting People and the Environment

Presentation to the ACRS Subcommittee

AREVA EPR Design Certification Application Review

Safety Evaluation Report with Open Items

Chapter 15, Group 2: Transient and Accident Analyses

August 18, 2011

Staff Review Team

- **Technical Staff**
  - **Fred Forsaty**
    Reactor Systems, Nuclear Performance, and Code Review Branch
  - **Project Managers**
    Getachew Tesfaye
    Jason Carneal

Overview of DCA

SRP Section/Application Section		No. of Questions	Number of OI
15.6.5*	Loss of Coolant Accidents Resulting from Spectrum of Postulated Piping Breaks Within the Reactor Coolant Pressure Boundary	113	10
Totals**		113	10

*The Phase 2 safety evaluation for Section 15.6.5, “Loss of Coolant Accidents Resulting from Spectrum of Postulated Piping Breaks Within the Reactor Coolant Pressure Boundary,” does not contain the evaluation of in-vessel downstream effects. This topic will be delivered in Phase 4 for the U.S. EPR design certification application.

** Question totals do not include open questions relating to in-vessel downstream effects.

Description of Open Items

- RAI 493, Question 15.06.05-98 : Tracks the ongoing review of ANP-10278P, "U.S. EPR Realistic Large Break Loss of Coolant Accident Methodology Topical Report." Final SER is currently in concurrence.

- RAI 493, Question 15.6.5-113: The staff requested that the applicant provide the validation of S-RELAP to model counter-current flow and demonstrate the applicability of the data obtained at scaled facilities to the U.S. EPR.

- RAI 403, Question 15.06.05-61: The staff requested that the applicant provide a mass balance accounting for the steam and condensate generated in accident conditions.

- RAI 403, Question 15.06.05-62: The staff requested that the applicant explain the dynamics of reboration of the crossover pipe in any idle loop prior to restart during SBLOCA.

- RAI 403, Question 15.06.05-63: The staff requested that the applicant explain how the entire matrix of relevant tests conducted at PKL or other facilities validates the assumptions in the boron dilution analysis for the U.S. EPR

Description of Open Items

- RAI 403, Question 15.06.05-70: The staff requested the applicant justify the minimum gap resistance value used in the SBLOCA analysis.

- RAI 493, Question 15.06.05-99: The staff requested that the applicant explain any impact of debris from the sump blocking portions of the core inlet on precipitation timing for the U.S. EPR design.

- RAI 493, Question 15.06.05-100: The staff requested that the applicant explain if the mixing volume in the SBLOCA analysis considers the maximum content of sump debris that can accumulate in the core.

- RAI 403, Question 15.06.05-66: The staff requested that the applicant describe the entrainment model and show the results demonstrating that the hot leg ECCS injection is effective in preventing boron precipitation.

- RAI 403, Question 15.06.05-68: The staff requested that the applicant show the timing to boric acid precipitation under specific flow conditions and using limiting conditions for the analysis.

Large-Break Loss-of Coolant-Accident Summary of Application

- The analytical methodology used to analyze this event is described in ANP-10278P, “U.S. EPR Realistic Large Break Loss of Coolant Accident Topical Report,” Revision 1, January 2010.
- The realistic LBLOCA methodology consists of the following computer codes:
  - S-RELAP5 for system thermal-hydraulic calculations.
  - RODEX3A is used for computation of the initial fuel stored energy, fission gas release, and fuel-cladding gap conductance.

Large-Break Loss-of Coolant-Accident Summary of Application (continued)

- The applicant's RLBLOCA methodology is based upon nonparametric statistics.
- A spectrum of break size and break type (double-ended guillotine break (DEGB) or split break) is analyzed for both the first core cycle and an equilibrium reload cycle.
- Each break spectrum is analyzed by making 124 S-RELAP5 simulations.
- Three safety parameters are obtained from the RLBLOCA analysis: The PCT; the maximum total local cladding oxidation; and the maximum core wide cladding oxidation.

Regulatory Guidelines:

- General Design Criterion (GDC) 13, “Instrumentation and Control,” as it relates to the availability of instrumentation to monitor variables and systems.
- GDC 35, “Emergency Core Cooling,” as it relates to demonstrating that the ECCS would provide abundant emergency core cooling (ECC) to satisfy the ECCS safety function.
- 10 CFR 50.46, “Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors,” as it relates to ECCS equipment being provided that refills the vessel in a timely manner for a LOCA

Initial Power:

- The initial core power was initial sampled over ±22.0 MWt interval about the licensed power level.
- The staff expressed its concern that the analysis should not be performed at less than the full licensed power level. The applicant agreed that it would treat core power deterministically.

Fuel Temperature Initialization:

- FRAPCON-3.3 calculation showed that RODEX3A underestimated fuel centerline temperature by ~300°F at the limiting burnup
- RODEX4 confirms FRAPCON-3.3 results.
- AREVA implemented a burnup-dependent fuel thermal conductivity adjustment to RODEX3A

Large-Break Loss-of Coolant-Accident (continued)

- The staff has issued a draft SER on ANP-10278P.
- A staff presentation was made to ACRS in March, 2011.
- The staff is currently processing the final SER.

Open Item:

- RAI 493 Question 15.06.05-98 will track ANP-10278P until the approved version of the topical report is issued.

Conclusions:

- Except for the open item identified above relating to the ongoing review of ANP-10278P, the staff concludes that applicable rules, regulations and guidelines are satisfied with respect to LBLOCA.

Small-Break Loss-of Coolant-Accident Summary of Application

- The analytical methodology used to analyze this event is described in approved topical report ANP-10263P-A, “Codes and Methods Applicability Report for the U.S. EPR,” August, 2007.
- Technical Report ANP-10291P, “Small Break LOCA and Non-LOCA Sensitivity Studies and Methodology,” October 2007, describes SG nodalization sensitivity analyses performed to support the SBLOCA methodology.

Small-Break Loss-of Coolant-Accident Summary of Application (continued)

- The appropriate conservatisms, prescribed by 10 CFR Part 50, Appendix K are incorporated in SBLOCA analysis.
- The computer codes used in this analysis are:
  - S-RELAP5 for system thermal-hydraulic calculations.
  - RODEX2-2A is used for computation of the initial fuel stored energy, fission gas release, and fuel-cladding gap conductance.

Regulatory Guidelines:

- GDC 13, "Instrumentation and Control," as it relates to the availability of instrumentation to monitor variables and systems.
- GDC 35, "Emergency Core Cooling," as it relates to demonstrating that the ECCS would provide abundant emergency core cooling (ECC) to satisfy the ECCS safety function.
- 10 CFR 50.46, "Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors," as it relates to ECCS equipment being provided that refills the vessel in a timely manner for a LOCA

Technical Topics of Interest
Section 15.6.5.2
Small Break Loss of Coolant Accident

Open Item RAI 493, Question 15.06.05-113

- The staff requested that the applicant provide the validation of S-RELAP to model counter-current flow, and demonstrate the applicability of the data obtained at scaled facilities to the U.S. EPR.
- The staff also requests that the applicant demonstrate applicability of the S-RELAP5 counter-current flow limitation model to the U.S. EPR.

Small-Break Loss-of Coolant-Accident (continued)

Conclusions:

- Except for the open item identified above, the staff concludes that applicable rules, regulations and guidelines are satisfied with respect to SBLOCA.

Post-LOCA Long-Term Cooling, Boron Dilution and Precipitation Summary of Application

The FSAR provides long-term cooling analyses in accordance with 10 CFR 50.46, to confirm that:

1. The core remains cooled for the duration of the two-phase long-term cooling (LTC) phase.
2. The boron concentration in the core keeps the core subcritical.
3. Boron precipitation will not obstruct core coolant flow.
4. Debris does not interrupt recirculation cooling.

Post-LOCA Long-Term Cooling, Boron Dilution and Precipitation (continued)

Regulatory Guidelines:

- GDC 13, “Instrumentation and Control,” as it relates to the availability of instrumentation to monitor variables and systems.
- GDC 35, “Emergency Core Cooling,” as it relates to demonstrating that the ECCS would provide abundant emergency core cooling (ECC) to satisfy the ECCS safety function.
- 10 CFR 50.46, “Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors,” as it relates to ECCS equipment being provided that refills the vessel in a timely manner for a LOCA.
- 10 CFR 50.46, as it relates to Paragraph (b)(5), “Long-term cooling.”

Core temperature shall be maintained at an acceptably low value and decay heat shall be removed for the extended period of time.

Open Item RAI 403, Question 15.06.05-61

- In response to Question 15.06.05-29, the applicant did not provide an assessment of the amount of condensate generated by reflux condensation as was requested.
- Instead, predictions for the liquid content in control areas defined as “steam generator (SG) outlet plenum,” “loop crossover pipe,” and “cold leg” were presented.

Open Item RAI 403, Question 15.06.05-62

- As follow-up to response to question 15.06.05-30, staff asked the applicant to demonstrate that deborated condensate accumulated in one or more loops (SG plena, loop seals, cold legs, downcomer) experiencing a complete or partial deprivation of SI will not pose a recriticality threat to the U.S. EPR.

Technical Topics of Interest Post-LOCA Long-Term Cooling, Boron Dilution and Precipitation (continued)

Open Item RAI 403, Question 15.06.05-63

- As follow-up to response to question 15.06.05-36, Staff asked the applicant to present the available experimental database pertaining to boron dilution relevant to the U.S. EPR boron dilution analysis. The staff considers limiting the database to Primärkreislauf-Versuchsanlage (PKL) Test F1.1 only, to be insufficient.

Open Item RAI 403, Question 15.06.05-70

- Follow-up to 241, Question 15.06.05-51, the staff questioned why credit for bypass identified as Path 1 in Figure 15.06-51-1 is appropriate and conservative.

Technical Topics of Interest Post-LOCA Long-Term Cooling, Boron Dilution and Precipitation (continued)

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Open Item RAI 493, Question 15.06.05-99

- Explain if debris from the sump blocks portions of the core inlet and if so, the impact on precipitation timing in the regions where the core boric acid cannot diffuse downward into the lower plenum.
- Identify the maximum core inlet blockage that can occur and show that local concentrations in the core are below the precipitation limit.
- With the core inlet blocked, and boric acid and other precipitates in the core, show that the switch to simultaneous injection can flush the core and reduce the concentration to acceptable levels.

Technical Topics of Interest Post-LOCA Long-Term Cooling (continued)

Open Item RAI 493, Question 15.06.05-100

- Explain if the mixing volume considers the maximum content of sump debris that can accumulate in the core.
- Provide and explain the value of the maximum amount (volume) of debris that can accumulate in the core and lower plenum regions during recirculation.

Open Item RAI 403, Question 15.06.05-66

- The staff requested that the applicant describe the entrainment model and show the results demonstrating that the hot leg ECCS injection is effective in preventing boron precipitation.

Technical Topics of Interest Post-LOCA Long-Term Cooling (continued)

U.S.NRC
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Protecting People and the Environment

Open Item RAI 403, Question 15.06.05-68

- The average concentration of all of the boric acid sources was calculated to be 1,929 ppm based on their volumetric contents and boric acid concentrations.
- Since liquid from the various sources is injected into the reactor coolant system (RCS) at individual flow rates and concentrations over different periods of time, setting the concentration of the fluid entering the core equal to the volume-averaged value is not justified.
- Show the timing to boric acid precipitation under specified flow conditions

Post-LOCA Long-Term Cooling

Conclusions:

EPR Post-LOCA Long-Term Cooling, Boron Dilution and Precipitation application is under the review process. Conclusion on these subjects will be made in phase 4 of the review upon resolution of the open items identified and the resolution of in-vessel downstream effects.

Acronyms

- CFR – Code of Federal Regulations
- DEGB – Double Ended Guillotine Break
- ECCS – Emergency Core Cooling System
- FSAR – Final Safety Analysis Report
- GDC – General Design Criterion
- LBLOCA – Large Break Loss of Coolant Accident
- LOCA – Loss of Coolant Accident
- LTC – Long Term Cooling
- PKL - Primärkreislauf-Versuchsanlage
- RAI – request for additional information
- RLBLOCA – Realistic Large Break Loss of Coolant Accident
- SBLOCA – Small Break Loss of Coolant Accident
- SER – Safety Evaluation Report
- SG – Steam Generator
- SI – Safety Injection

UNISTAR NUCLEAR ENERGY

Presentation to ACRS
U.S. EPR™ Subcommittee
Calvert Cliffs Nuclear Power Plant Unit 3
FSAR Chapter 15, Transient and Accident Analysis
August 18, 2011

Introduction

- RCOLA authored using ‘Incorporate by Reference’ (IBR) methodology
- To simplify document presentation and review, only supplemental information, or site-specific information, or departures/exemptions from the U.S. EPR FSAR are contained in the Calvert Cliffs Unit 3 COLA
- AREVA U.S. EPR FSAR ACRS Meeting for Chapter 15, Part 1 – Transient and Accident Analysis occurred on February 7, 2011. The AREVA U.S. EPR FSAR ACRS Meeting for Chapter 15, Part 2 – Transient and Accident Analysis occurred on August 18, 2011.

Introduction

- Today's Presentation was prepared by UniStar and is supported by AREVA (U.S. EPR Supplier).
  - Tim Kirkham (UniStar - Senior Health Physicist)
  - John N. Hamawi, Ph. D. (AREVA –Advisory Engineer)
  - Jerald Holm (AREVA –Licensing Engineer)
- Today Greg Gibson, UniStar Senior Vice President – Regulatory Affairs, will present the Calvert Cliffs Unit 3 FSAR Chapter 15.
- The focus of today's presentation will be on site-specific information that supplements the U.S. EPR FSAR.

Chapter 15, Transient and Accident Analysis Agenda

- Chapter 15, Transient and Accident Analysis
  - COL Information/Interface Items
  - Departures/Exemptions
- Conclusions

Chapter 15, Transient and Accident Analysis COL Information Items

- <u>Transient Analysis with Incore Trips</u>
- UNE will provide for NRC review, prior to the first cycle of operation, a report that demonstrates compliance with the following items:
  - Examine fuel assembly characteristics to verify that they are hydraulically compatible based on the criterion that a single package of assembly specific critical heat flux (CHF) correlations can be used to evaluate the assembly performance.
  - Verify that uncertainties used in the setpoint analyses are appropriate for the plant and cycle being analyzed.
  - Verify that the departure from nucleate boiling ratio (DNBR) and linear power density (LPD) satisfy specified acceptable fuel design limit (SAFDL) with a 95/95 assurance.

Chapter 15, Transient and Accident Analysis
COL Information Items

- Transient Analysis with Incore Trips (continued)
- Review the U.S. EPR FSAR Tier 2 analysis results for the first cycle to confirm that the static setpoint value provides adequate protection for at least three limiting anticipated operational occurrences (AOO).

Chapter 15, Transient and Accident Analysis Departures/Exemptions

- <u>Site Specific χ/Q Values</u>
- Conservative estimates of atmospheric Accident values for the Exclusion Area Boundary (EAB), Low Population Zone (LPZ) and Main Control Room are presented in the U.S. EPR FSAR and bound the Calvert Cliffs Unit 3 values except the 0-2 hour value for the LPZ.
- The U.S.EPR FSAR provides the Accident χ/Q of 1.75E-04 sec/m^3 at the LPZ - 1.5 miles during the 0-2 hr period. The corresponding calculated site-specific short-term atmospheric dispersion factor for Calvert Cliffs Unit 3 is 2.151E-04 sec/m^3 which exceeds/departs from the U.S. EPR value.
- The site-specific Accident Dispersion factors were used in calculating doses from accident scenarios specified in the U.S. EPR FSAR Chapter 15. Calvert Cliffs Unit 3 doses are conservatively within the limitations of 10 CFR 50.34 and GDC 19.

Chapter 15, Transient and Accident Analysis Departures/Exemptions

Table 15.0-2— {CCNPP Unit 3 LPZ Radiological Consequences of U.S. EPR Design Basis Accidents}

Design Basis Accident		Offsite Dose CCNPP Unit 3 LPZ rem (TEDE)	Acceptance Criterion rem (TEDE)
LOCA		9.1	25
Small line break outside of Reactor Building		0.4	2.5
SGTR	Pre-incident spike	0.3	25
	Coincident spike	0.3	2.5
MSLB	Pre-incident spike	0.1	25
	Coincident spike	0.2	2.5
	Fuel rod clad failure	2.6	25
	Fuel overheat	2.8	25
RCP locked rotor/broken shaft		0.9	2.5
Rod ejection		3.4	6.3
Fuel handling accident		1.2	6.3

Chapter 15, Transient and Accident Analysis
Agenda

- Chapter 15, Transient and Accident Analysis
  - COL Information/Interface Items
  - Departures/Exemptions
- Conclusions

Conclusions

- One COL Information Item, as specified by U. S. EPR FSAR, is addressed in Calvert Cliffs Unit 3 FSAR Chapter 15, Transient and Accident Analysis.
- One Departure/ One Exemption in Chapter 15 from the U.S. EPR FSAR for Chapter 15 of the Calvert Cliffs Unit 3 FSAR.
- There are no NRC SER Open Items or Confirmatory Items
- No ASLB Contentions
- Responses to all RAIs have been submitted.

Acronyms

- ACRS – Advisory Committee on Reactor Safeguards
- AOO – Anticipated Operational Occurrences
- ASLB – Atomic Safety & Licensing Board
- CHF – Critical Heat Flux
- COL – Combined License
- COLA – Combined License Application
- DNBR – Departure from Nucleate Boiling Ratio
- EAB – Exclusion Area Boundary
- FSAR – Final Safety Analysis Report
- IBR – Incorporate by Reference
- LOCA – Loss of Coolant Accident
- LPD – Linear Power Density
- LPZ – Low Population Zone
- NRC – Nuclear Regulatory Commission
- MSLB – Main Steam Line break
- RCOLA – Reference COL Application
- RCP– Reactor Coolant Pump
- SAFDL – Specified Acceptable Fuel Design Limit
- SER – Safety Evaluation Report
- SG – Safety Guide
- SGTR – Steam Generator Tube Rupture
- TEDE – Total Effective Dose Equivalent

Presentation to ACRS U.S. EPR Subcommittee Design Certification Application FSAR Chapter 15 Group 2 - LOCA

August 18, 2011

EPR™ by AREVA

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Agenda

▶ U.S. EPR Small Break LOCA	Liliane Schor
▶ U.S. EPR Large Break LOCA	Kent Abel
▶ U.S. EPR Coolable Geometry and Long Term Cooling Issues	Don Rowe Lisa Gerken

Related Previous ACRS Meetings

U.S. EPR Methods	September 9, 2009
U.S. EPR Non-LOCA FSAR	February 7, 2011
U.S. EPR SBLOCA Methods	February 8, 2011
U.S. EPR LBLOCA Methods	March 23, 2011

10 CFR 50.46 Acceptance Criteria

- **The calculated maximum fuel element cladding temperature shall not exceed 2200°F.**
- **The calculated total oxidation of the cladding shall nowhere exceed 0.17 times the total cladding thickness before oxidation.**
- **The calculated total amount of hydrogen generated from the chemical reaction of the cladding with water or steam shall not exceed 0.01 times the hypothetical amount that would be generated if all of the metal in the cladding cylinders surrounding the fuel, excluding the cladding surrounding the plenum volume, were to react.**
- **Calculated changes in core geometry shall be such that the core remains amenable to cooling.**
- **Long term coolability is maintained.**

U.S. EPR SBLOCA Analysis

Liliane Schor

Supervisory Engineer, LOCA Analysis

SBLOCA Methodology

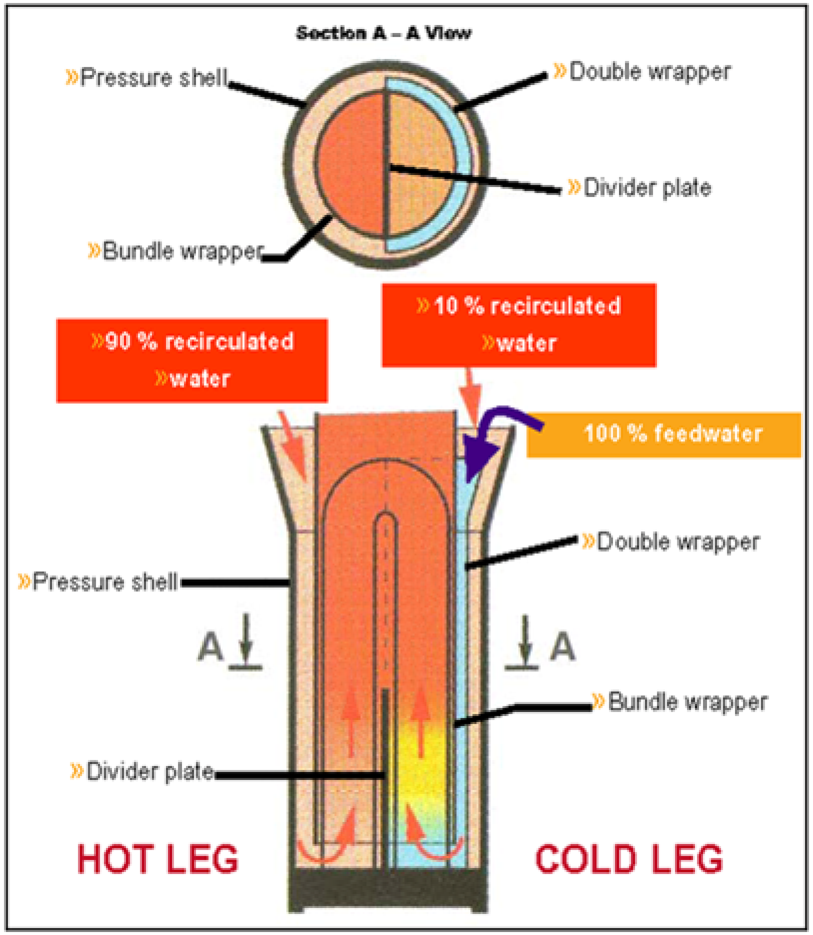
- Key codes used in SBLOCA methodology
  - RODEX2-2A - Prediction of fuel-to-cladding gap conductance, fuel temperatures, fuel rod gap composition, and fuel rod internal pressures as a function of power and exposure
  - S-RELAP5 - System thermal-hydraulic response calculations

ACRS Questions Relevant To SBLOCA

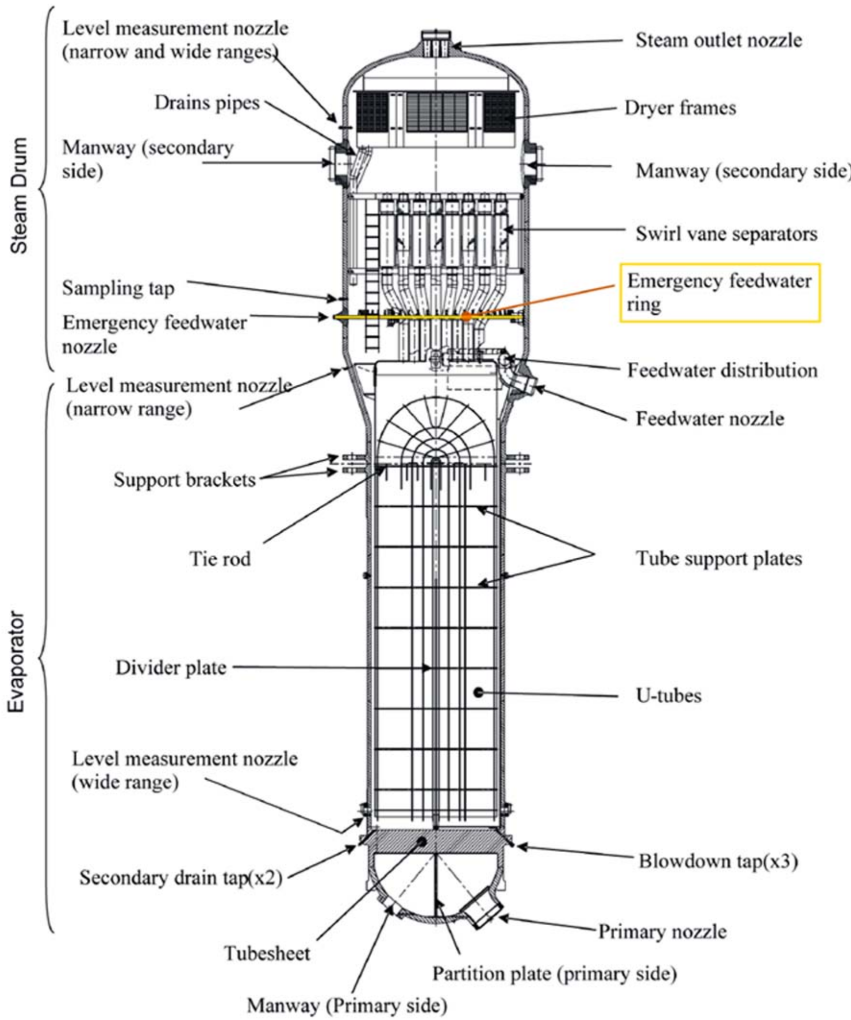
- Steam Generator modeling
- CCFL
- LOBI SBLOCA tests
- Controlled depressurization

Steam Generator Secondary Response

- **The SG is a boiler with an axial economizer**
  - A divider plate separates the cold leg and hot leg sides of the tubes
  - MFW is directed between the bundle wrapper and the double wrapper; all MFW proceeds to the cold side
  - Nodalization represents the physical configuration
- **Multi dimensional effects will occur above the partition plate,**
  - Good mixing expected, 2D modeling not necessary
- **MFW terminates at scram (LOOP, no LOOP)**
  - LOOP case: EFW automatically initiated. EFW injects in a feed ring similar to other SGs, equal partition on the downcomer, MSIV closed, no recirculation (due to low efficiency of the separator at low flows)
  - No LOOP, EFW initiated on low WR level, not initiated for all breaks (except 2 inch)



Steam Generator

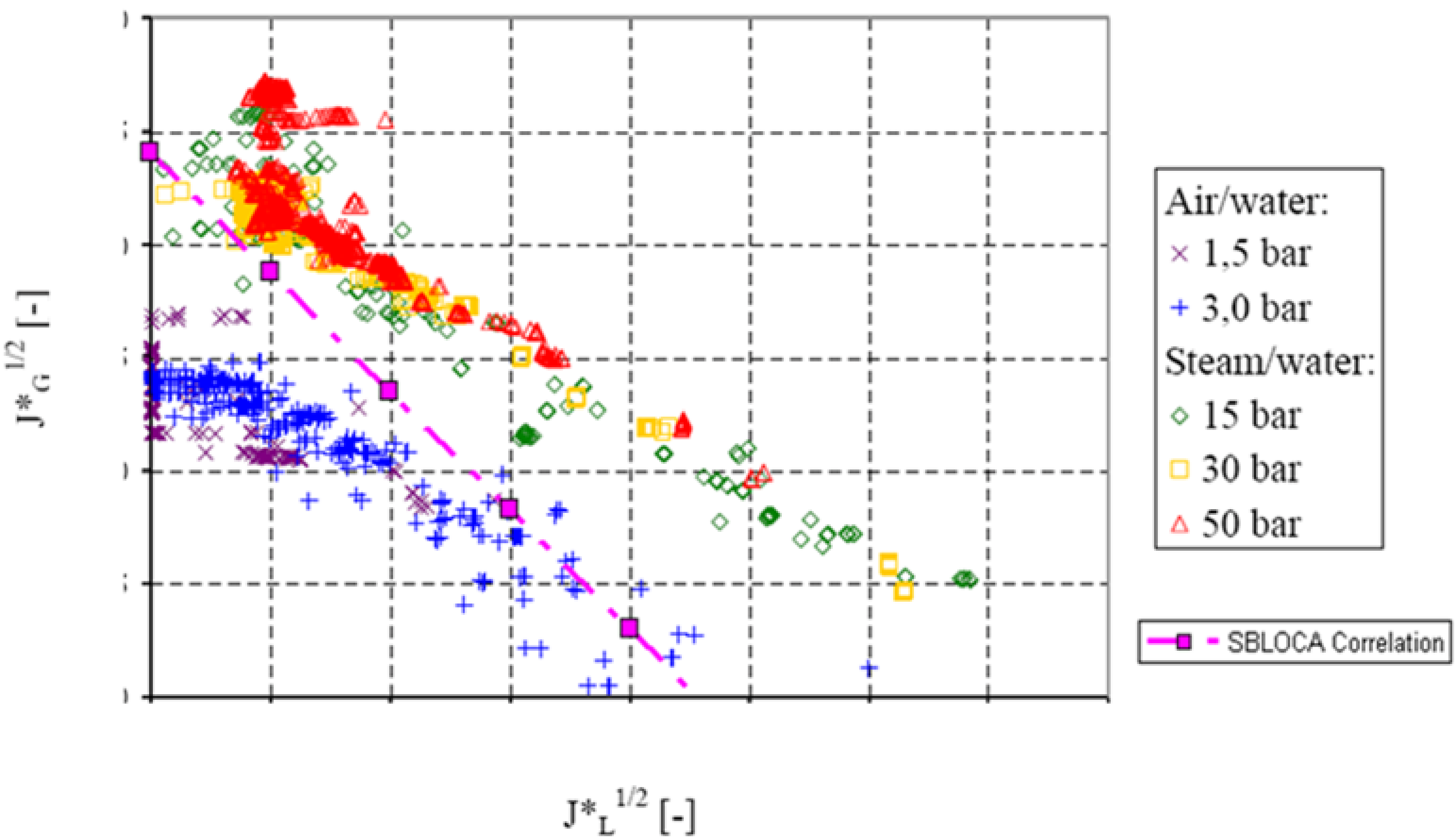


CCFL

- U.S. EPR SBLOCA model uses Wallis CCFL correlation at the inlet to the SG plenum

- The correlation was assessed against:
  - UPTF test 11
  - ROSA IV
  - Semiscale S-UT-08
  - BETHSY 9.1b

SBLOCA Hot Leg-SG Inlet CCFL Compared to TOPFLOW CCFL Data



LOBI SBLOCA Tests

- **LOBI SBLOCA Test KWU-PWR, 4 loop PWR**
  - **A2-81 (ISP 18) - 1% Cold Leg Break SBLOCA**
    - Forced Circulation Phase
      - Break opens, primary pressure decreases to 13.2 MPa within 32 seconds, reactor scram, SG isolation
      - Secondary cooling activated
      - 45 seconds, pumps coast down starts, 75 sec HPIS starts to inject
    - Pumps coast stops at 121 seconds, two-phase natural circulation, followed by voiding & reflux condensation
    - No uncovery, hard to determine the effect of reflux cooling
  - **Test LOBI – BL06-Break 3 mm**
    - Opening the break to pump stop (0-2790 sec)
      - CCFL to the inlet of intact loop SG
    - From pump stop to end of accumulator injection (2790-3850 sec)
      - Reflux cooling
    - End of accumulator injection to final core rewetting (3850-6900 sec)
    - Interesting test, but similar to BETHSY 9.1b
  - **These tests were assessed by CAMP members with RELAP5/Mod 2 & RELAP5/Mod3 and showed acceptable results. We did not benchmark our code against these tests, but we would expect similar results.**

Controlled Depressurization

- **BETSHY TEST 9.1 b**
  - **SBLOCA (~0.5%) in the loop with pressurizer**
  - **Three different phases**
    - Subcooled blowdown
    - Mass depletion in primary side
    - Ultimate procedure
  - **Steam Generator Blowdown /Reflux Condensation (Ultimate Procedure)**
    - Fully opening the dump valves in secondary side to depressurize the primary
    - Starts at 2562 seconds and ends with accumulator isolation at about 3831 seconds
      - Intense condensation in the tubes induces liquid fall back to the core, which is cooled from the top, then accumulator cools the rods.
    - Period with no ECCS injection, no heatup, primary pressure drops to LPSI actuation, 5177 seconds
    - Very early after injection, LPSI flow becomes larger than break flow and the primary is recovered.
- **Good prediction of this test by S-RELAP5 and also scales reasonably to the U.S. EPR**

Unique U.S. EPR Design Features for SBLOCA

- **Safety related systems and features**
  - **Four trains of Accumulators, MHSI, LHSI/RHR, EFW, MSRT**
  - **LHSI cross-connects opened when one LHSI train is removed for preventive maintenance**
  - **Automatic partial cooldown of SGs on SI signal.**
  - **Automated trip of reactor coolant pumps on coincident SI actuation signal and low ΔP across the pumps**
  - **In-Containment Refueling Water Storage Tank**
    - Source of ECC water
    - No switchover needed
  - **Shallow cold leg cross-over piping/loop seal (top of loop seal at 30 mm below the top of the active core)**

Key Features of the Model

- **Two-dimensional hydrodynamic modeling applied in the downcomer and core.**
  - **Core divided into three hydrodynamic regions: hot assembly, inner region of core (~30% of the core), and outer region of core (~70% of the core).**
  - **Fuel represented by four heat structures: hot rod; hot assembly; inner, high-powered core region; outer, low-powered core region.**
- **Loop seals in two loops are biased downward to ensure consistent, conservative clearing**
  - **The broken loop and the intact loop closest to the break is biased downward by one foot.**
- **Conservative scram characteristics are assumed**
  - **Maximum time delay**
  - **Most reactive rod held out of the core**

Selected Initial Conditions

Parameter	Biasing	Analysis
Thermal Power, MW	Nominal + 0.048%	4612
Fq	Tech Spec Limit	Tech Spec Limit 2.6
FΔH	Tech Spec Limit	1.7
Axial Power Shape	Most top skewed over 8 possible cycles	EOC Top skewed
Reactor Coolant System Average Temperature, °F	Nominal	594 (above 60% power, $T_{average}$ is constant)
Reactor Coolant Flow Per Loop, gpm	Tech Spec Minimum with Bias for uncertainty	119,692
Secondary System Pressure, psia	At 100.5% power and 5% plugging	1103.2
Primary System Operating Pressure, psia	Nominal	2250
Pressurizer Level	Nominal	54.3%
Steam Generator Liquid Level	Corresponding to Power Level	49% NR
SG Tube Plugging	Assumed Maximum	5%
MHSI, LHSI, EFW Temperature, °F	Maximum Tech Spec Temperature for IRWST	122
Accumulator Pressure, psia	Minimum	652.7
Accumulator Temperature, °F	Nominal	90

SBLOCA Analysis

- **Break flow area ≤10% of the cold leg area**
- **Deterministic methodology**
- **Key parameters, such as protection system setpoints and ECCS performance, are biased for uncertainty in accordance with Regulatory Guide 1.105**
- **Other inputs are nominal**
- **Does not credit mitigating non-safety related systems**
- **Accumulators are isolated as soon as non-condensable gases are detected at their nozzles**
- **Analysis Assumptions**
  - Worst single-failure prevents operation of one train of pumped ECCS and EFW
  - One train of pumped ECCS and EFW is unavailable because of preventive maintenance
  - Startup times for pumped ECCS and EFW assume LOOP at scram and startup time of EDGs
  - Two operating trains of ECCS deliver water to broken and adjacent loops respectively
  - MFW is tripped-off at reactor scram

SBLOCA-Protection System Setpoints

Signal	Biasing	Analysis Assumption
Reactor Trip on Low Pressurizer Pressure, psia	Degraded for Harsh Conditions (-55 psia Uncertainty)	1950
Reactor Trip on Low Hot Leg Pressure, psia	Degraded for Harsh Conditions (-75 psia Uncertainty)	1930
Main Feedwater Isolation	-	Instantaneous for LOOP
Emergency Feedwater Initiation	Degraded for Harsh Conditions (-16.5% Uncertainty)	LOOP & SI 23.5% WR Level
Main Steam Relief Train Opening Pressure, psia	Nominal + Normal Uncertainty (+30 psia)	1414.7 psia in SG, before beginning of partial cooldown; then maintained at 180 °F/hr to 900 psia
Reactor Coolant Pump Trip	Degraded for Harsh Conditions (-5% Uncertainty)	LOOP Automatic, on coincident SI Signal + 75% ΔP across 2 pumps
Safety Injection Signal, Low-Low Pressurizer Pressure, psia	Degraded for Harsh Conditions (-55 psia Uncertainty)	1612.9

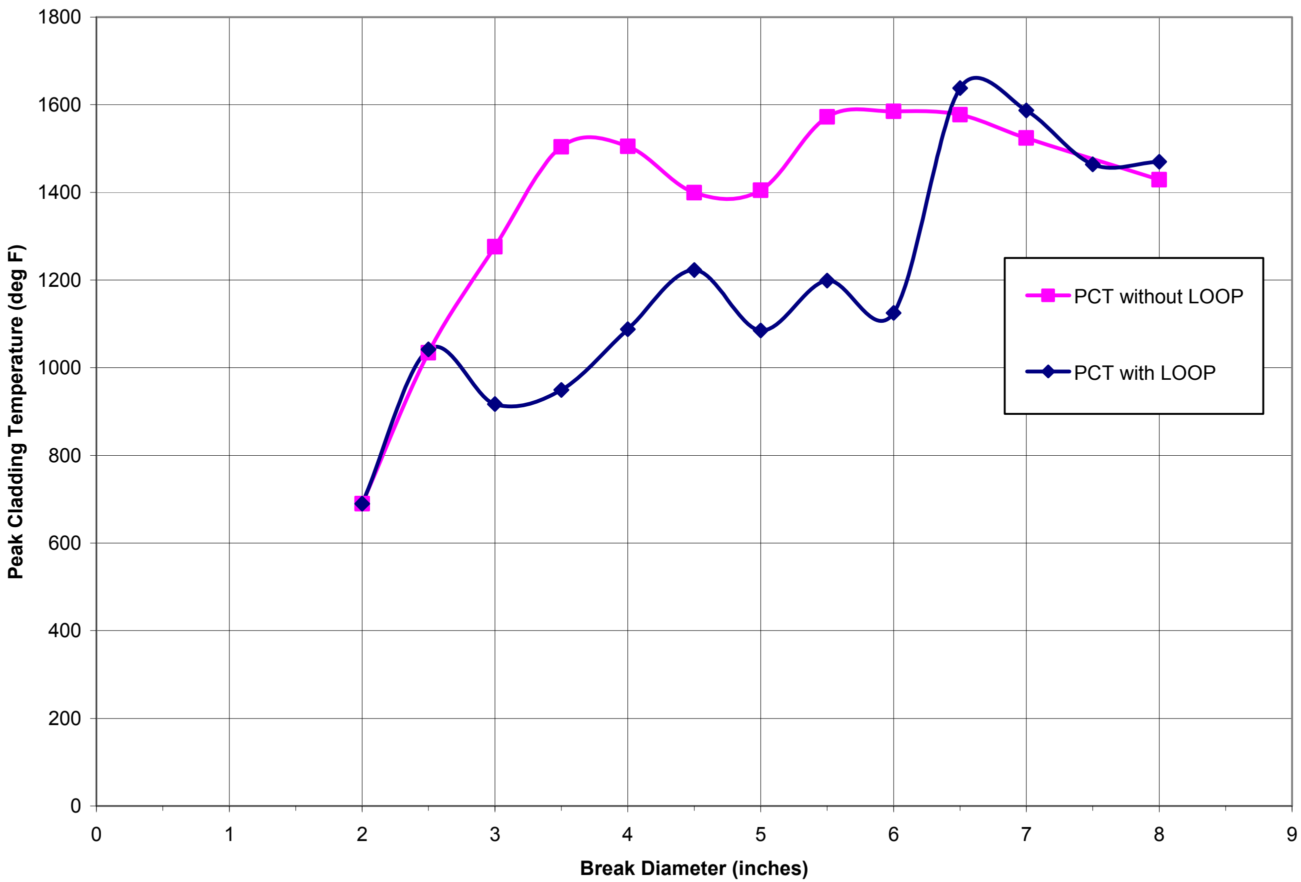
SBLOCA Break Spectrum Results (LOOP)

Break Diameter (in)	PCT (ºF)	Time of PCT (sec)	Metal Water Reaction	
			Local Maximum (%)	Core Wide (%)
2.0	No Heatup	N/A	N/A	N/A
2.5	1042	5000.2	2.59E-2	5.006E-4
3.0	917	2986.4	5.286E-3	1.806E-4
3.5	949	1837.9	5.458E-3	2.106E-4
4.0	1088	1222.3	1.551E-2	3.193E-4
4.5	1223	908.13	4.855E-2	8.999E-4
5.0	1085	679.28	1.176E-2	3.543E-4
5.5	1199	548.34	3.064E-02	6.715E-4
6.0	1125	459.28	1.758E-2	5.462E-4
6.5	**1638**	**360.26**	**0.383**	**8.974E-3**
7.0	1587	305.39	0.305	7.619E-3
7.5	1464	267.45	0.158	3.135E-3
8.0	1470	234.85	0.152	2.496E-3
ECCS Line Break	1531	265.16	0.217	5.076E-3
Max Break 9.71	1435	165.82	0.108	1.447E-3

No LOOP-Pump Trip Sensitivities

- The transient deck was modified to allow the following:
  - Change the delay on ECCS actuation and EFW actuation such that EDG delay was not taken into account
  - MFW coastdown over the time of MFW closure. Low-load MFW injection was neglected because it is a non-safety system.
  - The Main Steam Bypass was not used (isolation on high containment pressure) and the MSRT system was used for SG depressurization
  - The pumps were tripped on 75% ΔP across the pumps
  - EFW was actuated on low wide-range level

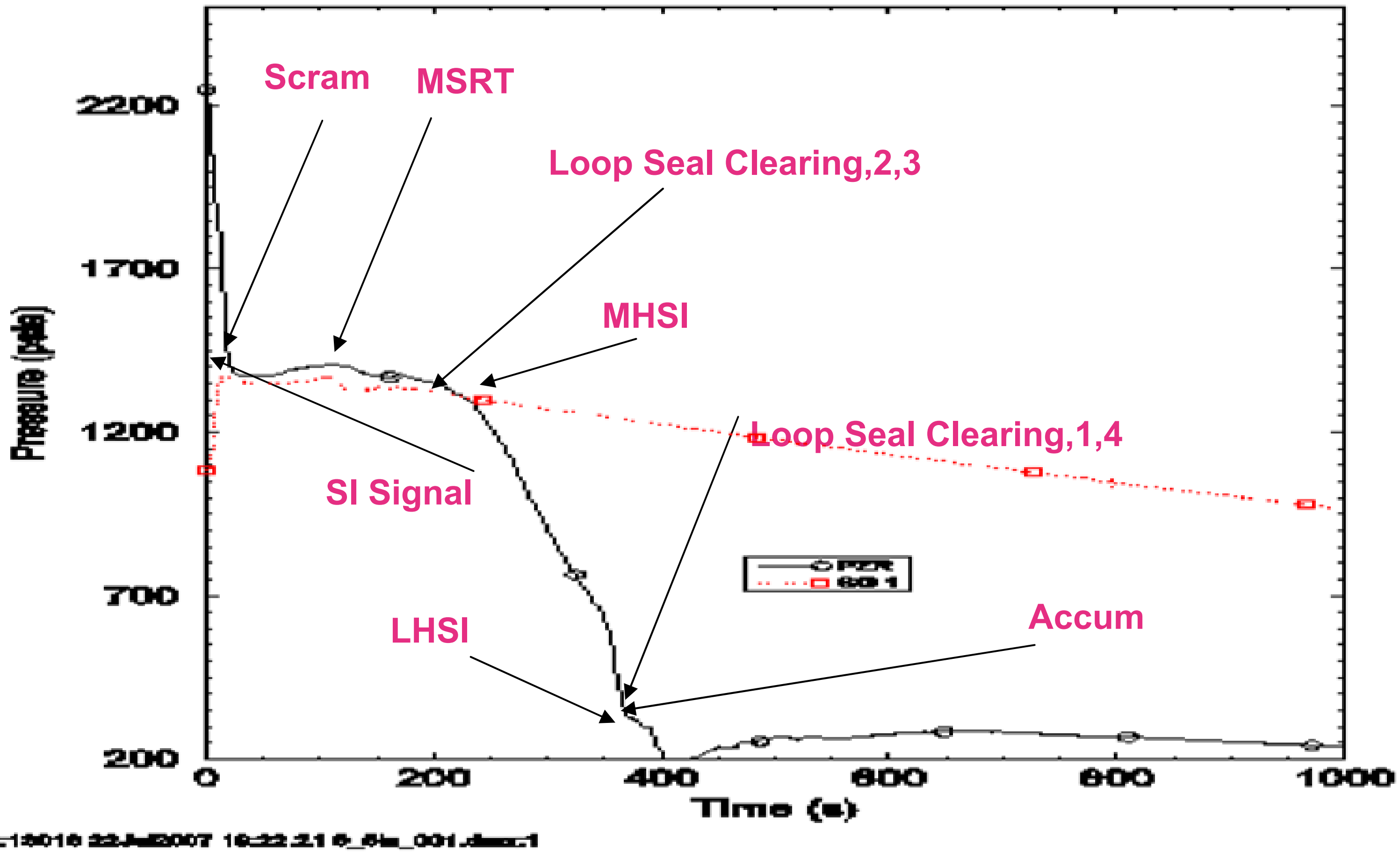
PCT Comparison LOOP/no LOOP (Pump Trip)



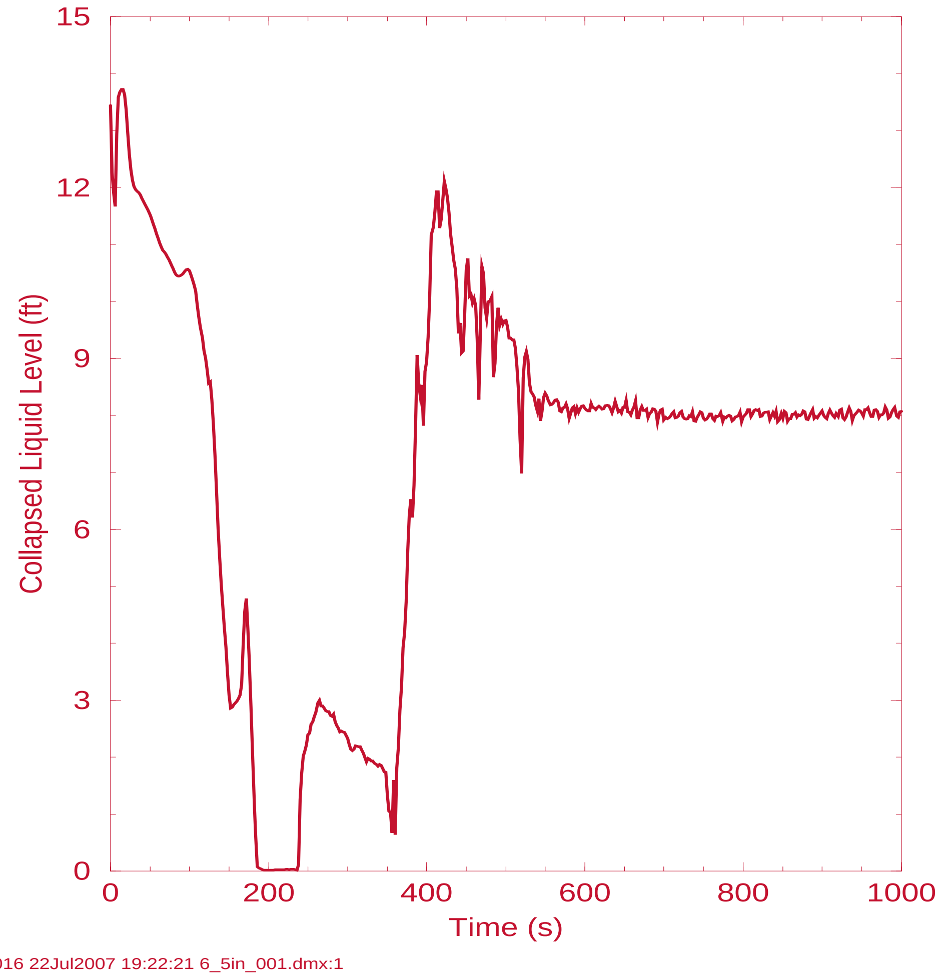
Limiting Break: 6.5 inch-LOOP, Sequence of Events

Time (sec)	Event
0	Break Open, Begin Analysis
4.493	Reactor Tripped on Low Hot Leg Pressure
16.807	SIS Signal on Low Pressurizer Pressure
76.807	Emergency Feedwater Initiated (Loop 1 and 4)
114	Main Steam Relief Isolation Valve opens
134	Main Steam Relief Control Valve closes (faster SG depressurization)
170	Main Steam Relief control Valve reopens to control SG depressurization at a rate of 180 °F/hr
234	Loop Seal Clearing – Loop 2
237	Loop Seal Clearing – Loop 3
246	Loop Medium Head Safety Injection (MHSI) Delivery Began (Loops 4 and 1)
250	Break uncovery
346	Accumulator Injection ((Loop 1, 2, 3 and 4 respectively)
360	Loop Seal Clearing (Loop 1)
360.26	PCT Occurred (1638, node #31)
362	Loop Seal Clearing (Loop 4)
380	LHSI Injection Begins (Loops 4, 1)
1000	Transient Calculation Terminated

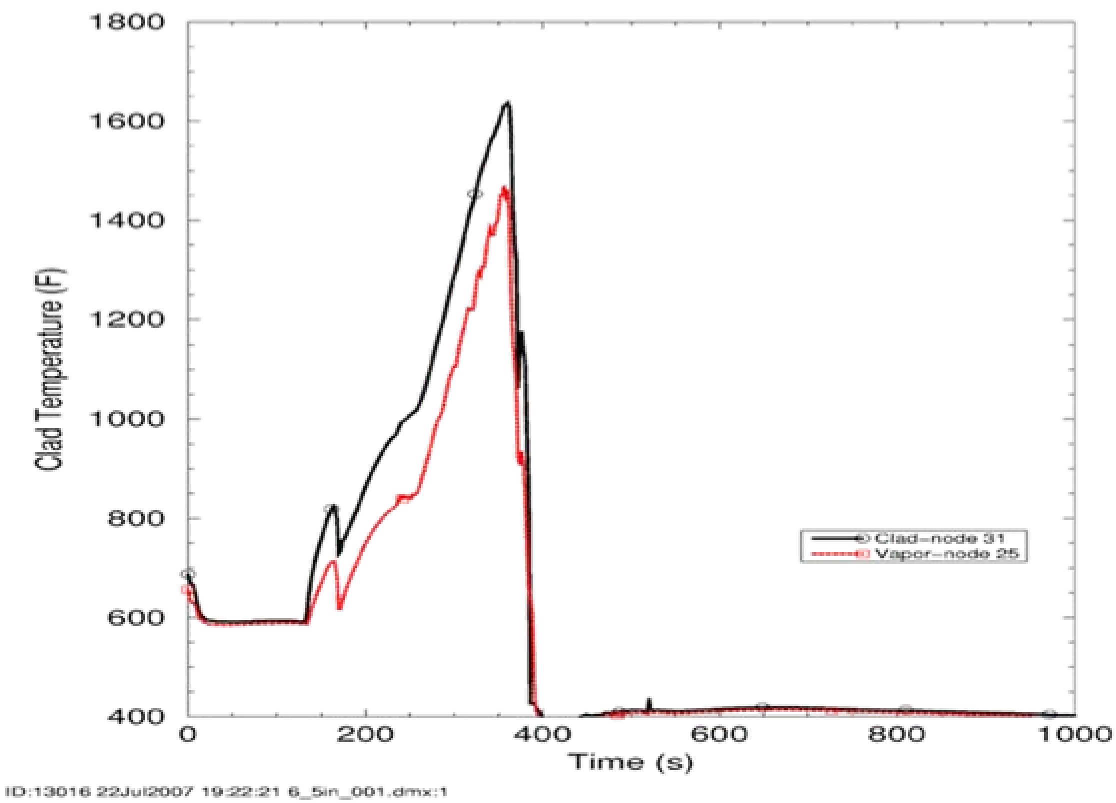
System Pressures



Hot Assembly Collapsed Liquid Level



Vapor and Clad Temperatures for Hot Node



Results

- PCT for a 6.5 in. break is 1638˚F, below the 2200˚F PCT limit specified in 10CFR50.46(b)(1).
- The total cladding oxidation at the peak location is below the 17% limit specified in 10CFR50.46(b)(2).
- The hydrogen generated in the core by cladding oxidation during these accidents is below the 1% limit specified in 10CFR50.46 (b)(3).

U.S. EPR LBLOCA Analysis

Kent Abel

U.S. EPR Design Features Important to LBLOCA

- Safety related systems and features
  - Passive containment heat sinks for containment heat removal
  - In-containment Refueling Water Storage Tank (IRWST)
    - Source of ECC water
  - Medium Head Safety Injection (MHSI)
  - Higher operating pressure in accumulators (~700 psia)
  - LHSI cross-connects opened when one LHSI train is removed for preventive maintenance

Realistic LBLOCA Methodology
Key Features

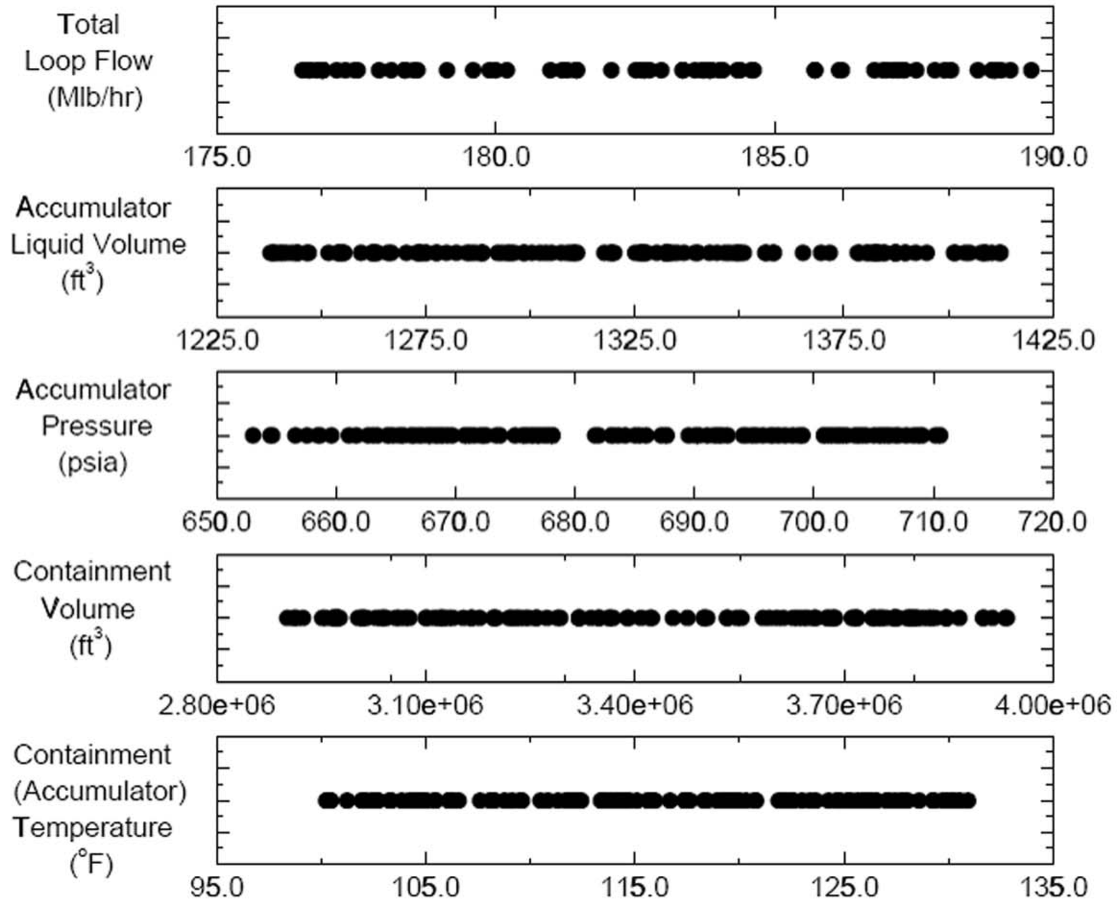
- **Probabilistic Methodology**
- **Two sets of 124 cases:**
  - **Initial Fuel Cycle**
  - **Equilibrium Fuel Cycle representative of an 18 month core**
    - A nominal cycle length of 18 months is the basis for all neutronic parameters

RLBLOCA EM

Example Sampled Plant Parameters

Parameter	Min	Max
Core power (MW) (not sampled)	4612	
Initial flow rate (Mlbm/hr)	176.44	198
Initial operating temperature (^{o}F)	590	598
Pressurizer pressure (psia)	2214	2286
Pressurizer level (%)	49.3	59.3
Containment volume (ft^3)	2888000	3934000
Containment temperature (^{o}F)	100	131
Accumulator pressure (psia)	652.7	710.7
Accumulator liquid volume (ft^3)	1236	1412.6

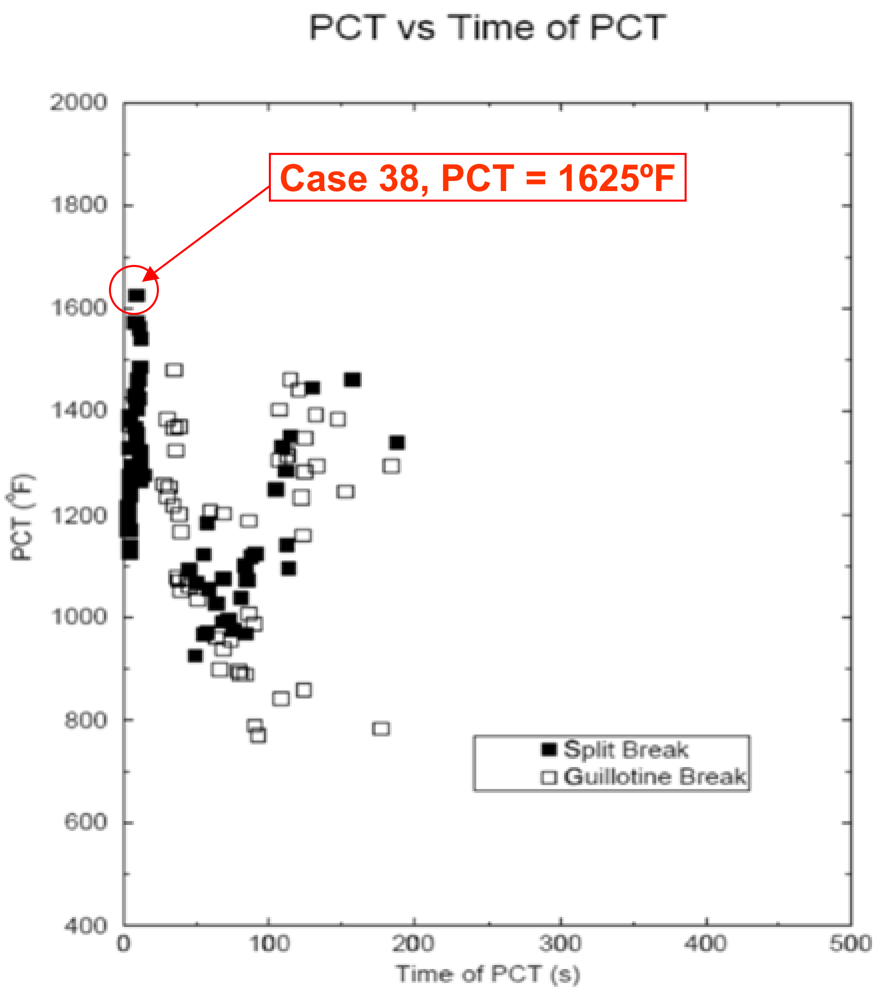
Equilibrium Cycle – Scatter Plots



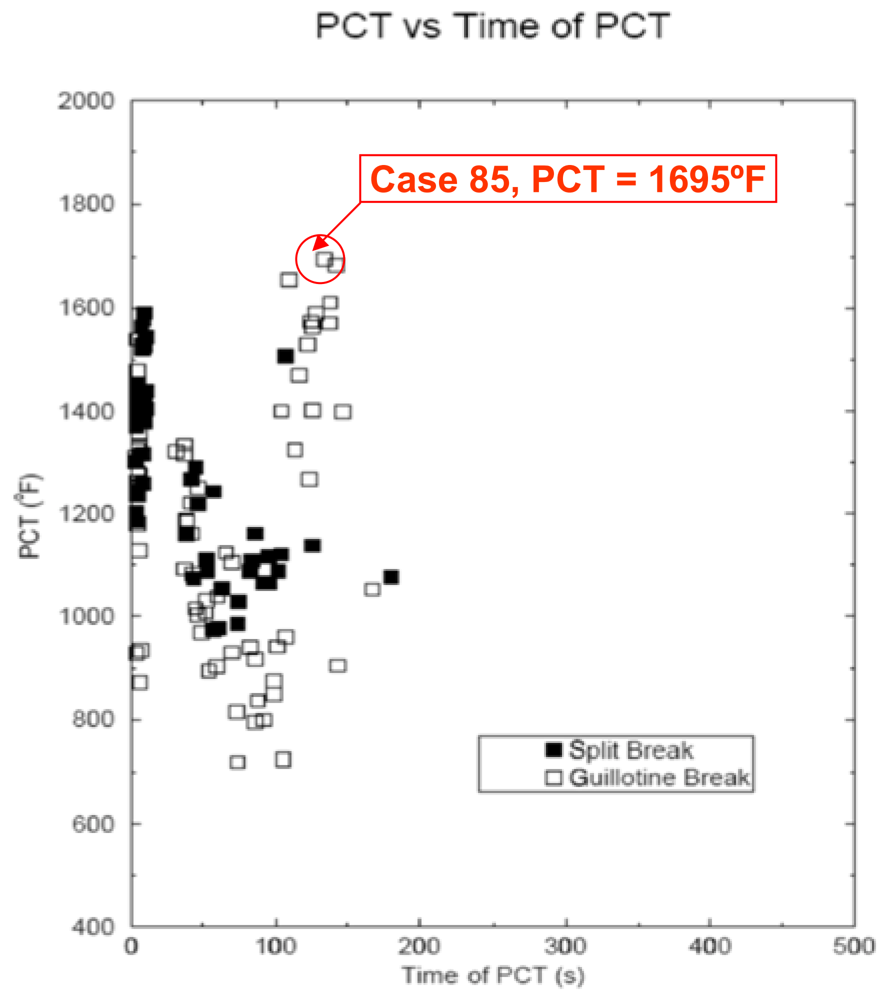
Denotes highest PCT case in each analysis

Acceptance Criteria:
PCT shall not exceed 2200ºF

Equilibrium Cycle



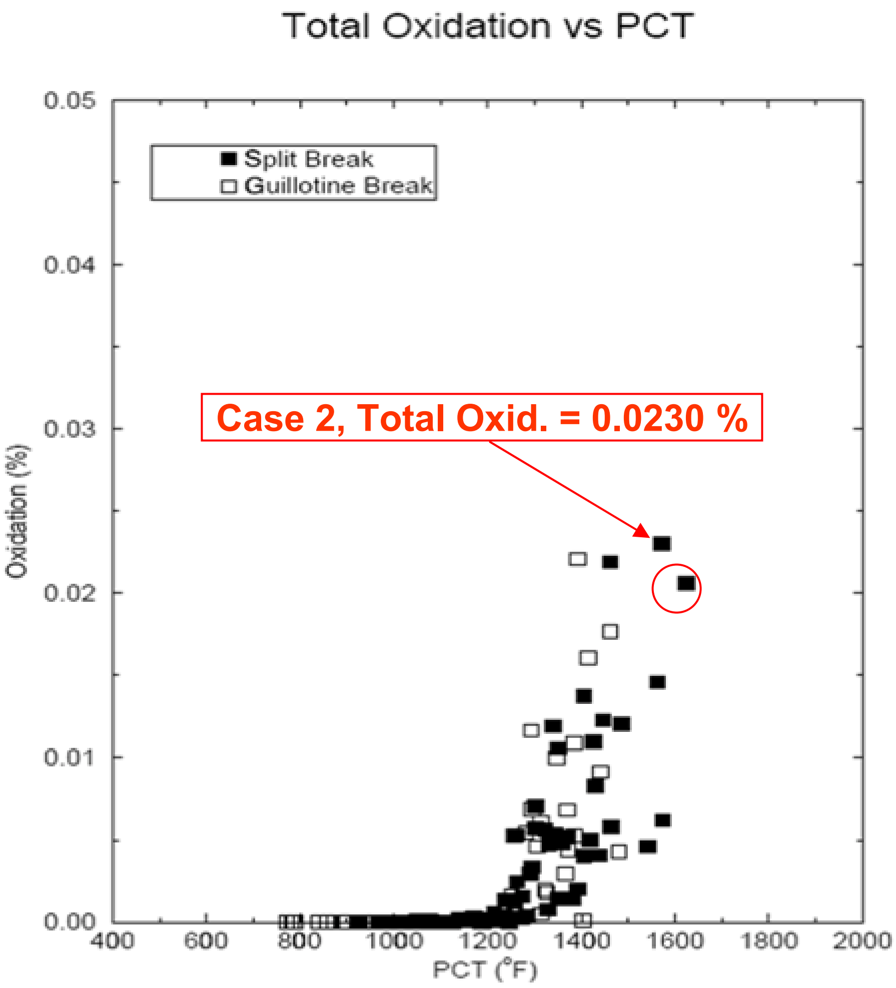
Cycle 01



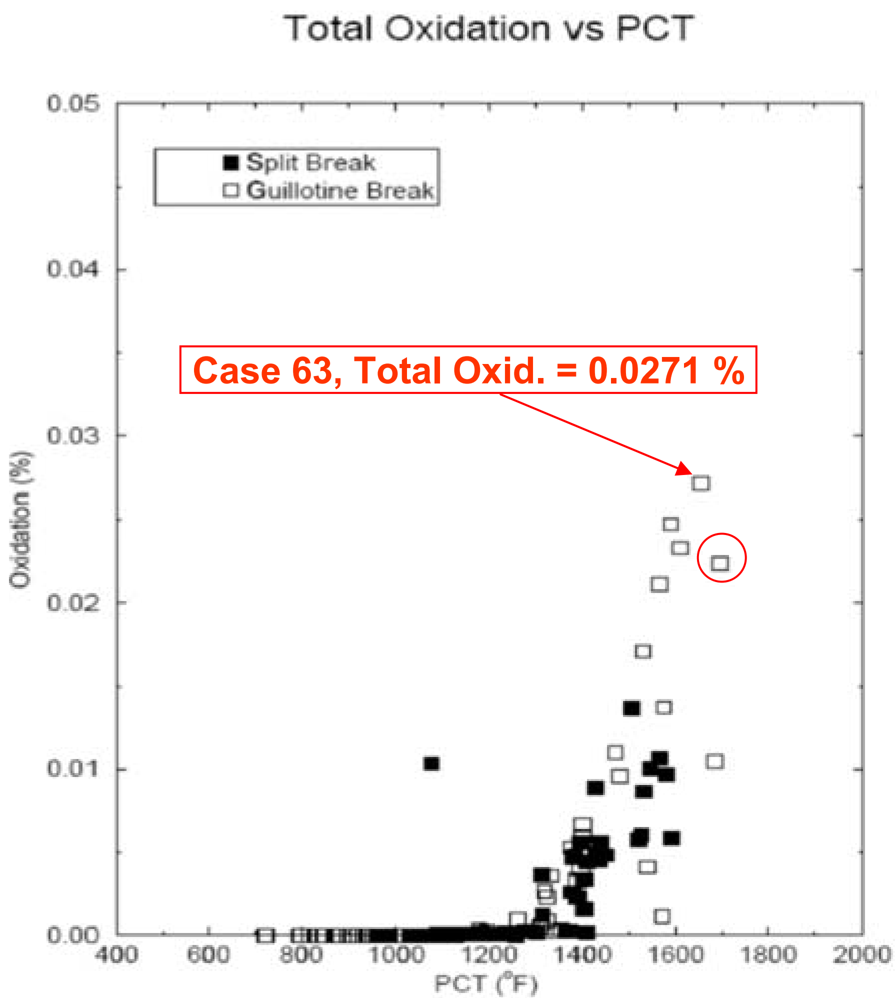
Denotes highest PCT case in each analysis

Acceptance Criteria:
Total percent oxidation of less than 1%

Equilibrium Cycle



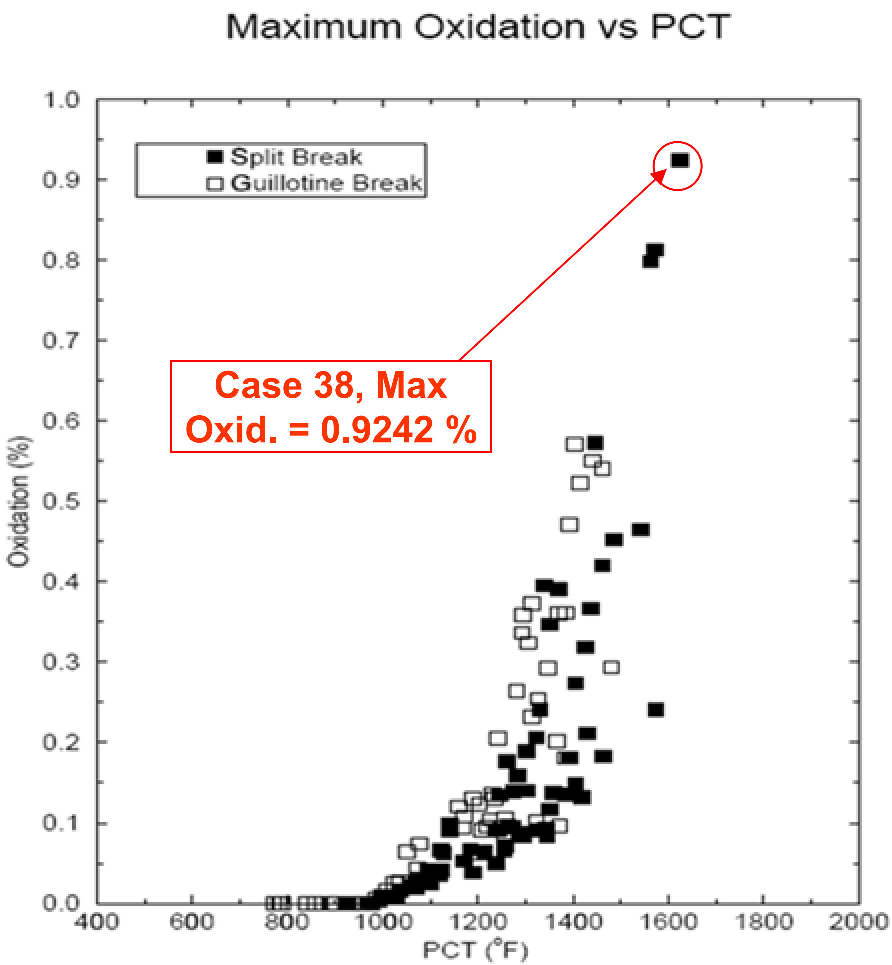
Cycle 01



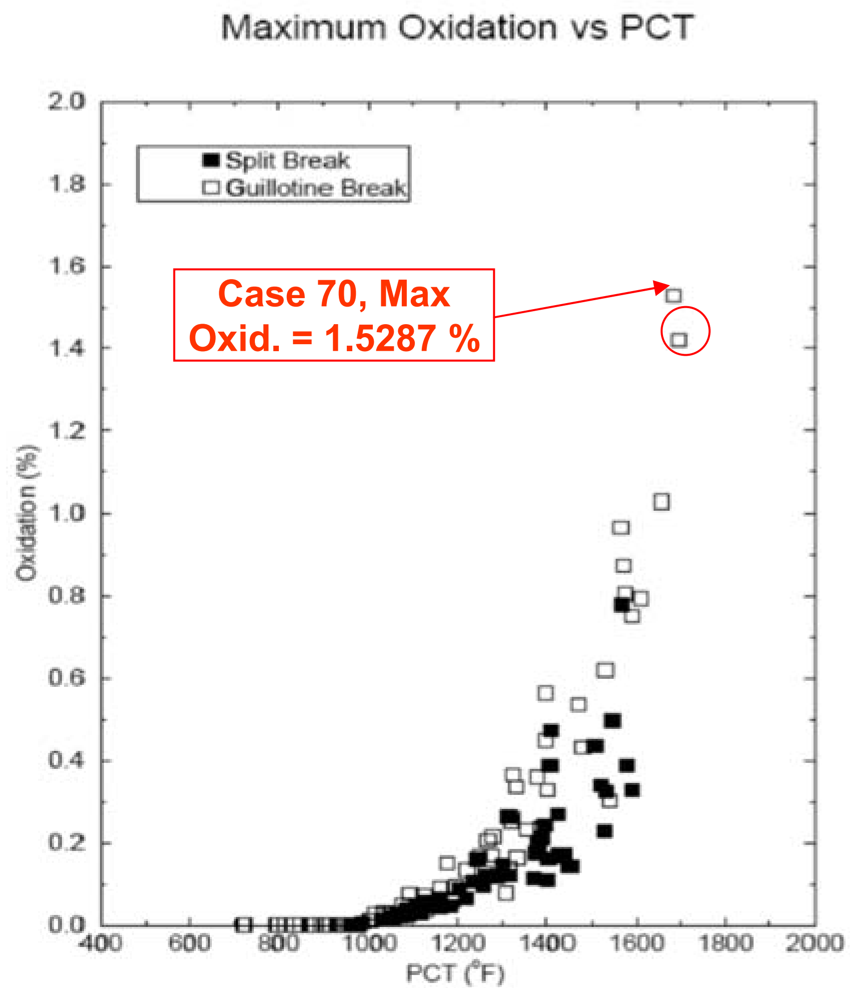
Denotes highest PCT case in each analysis

Acceptance Criteria:
Maximum cladding oxidation shall not exceed 17 percent total cladding thickness before oxidation.

Equilibrium Cycle



Cycle 01



ACRS Questions Relevant To LBLOCA

- Upstream conditions for Moby Dick test 3141
- S-RELAP5 treatment of nitrogen during critical flow

Upstream Conditions for Moby Dick

- **Moby Dick test 3141**
  - **Subcooled Conditions at Inlet**
  - **Water Injection P = 5.619E5 Pa = 81.52 psia**
  - **T = 308.7 K = 95.99 F**

Critical Flow at the Break with Noncondensables

- Based on HEM model
- Thermal equilibrium
- Pressure based on partial pressures of steam and noncondensables. Noncondensables treated as an ideal gas.

$$P = P_n + P_v$$

- Vapor properties obtained from steam tables and noncondensable gas state equations
- Remaining portion of critical flow calculation similar to critical flow without noncondensables present

U.S. EPR Long Term Cooling

Don Rowe
Lisa Gerken

Long Term Core Cooling

- **Long Term Core Cooling following a LOCA:**
  - **Mixture Level – Today**
  - **Boron Precipitation – Today**
  - ***Boron Dilution – Not addressed today***
  - ***GSI 191 – Not addressed today***

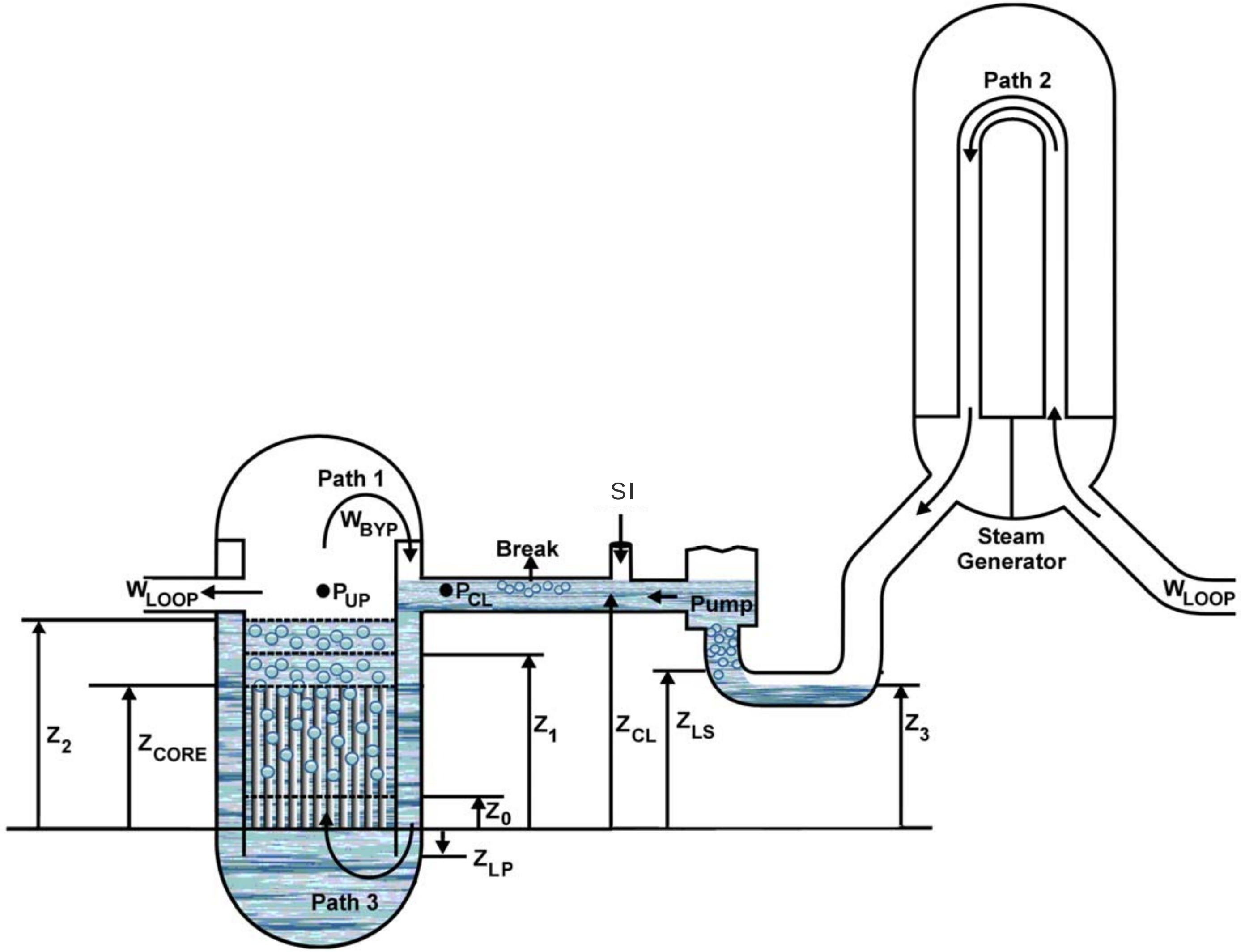
Long Term Core Mixture Level

- **Long Term Core Cooling Mixture Level**
  - **Assure core cooling during LOCA post-reflood period**

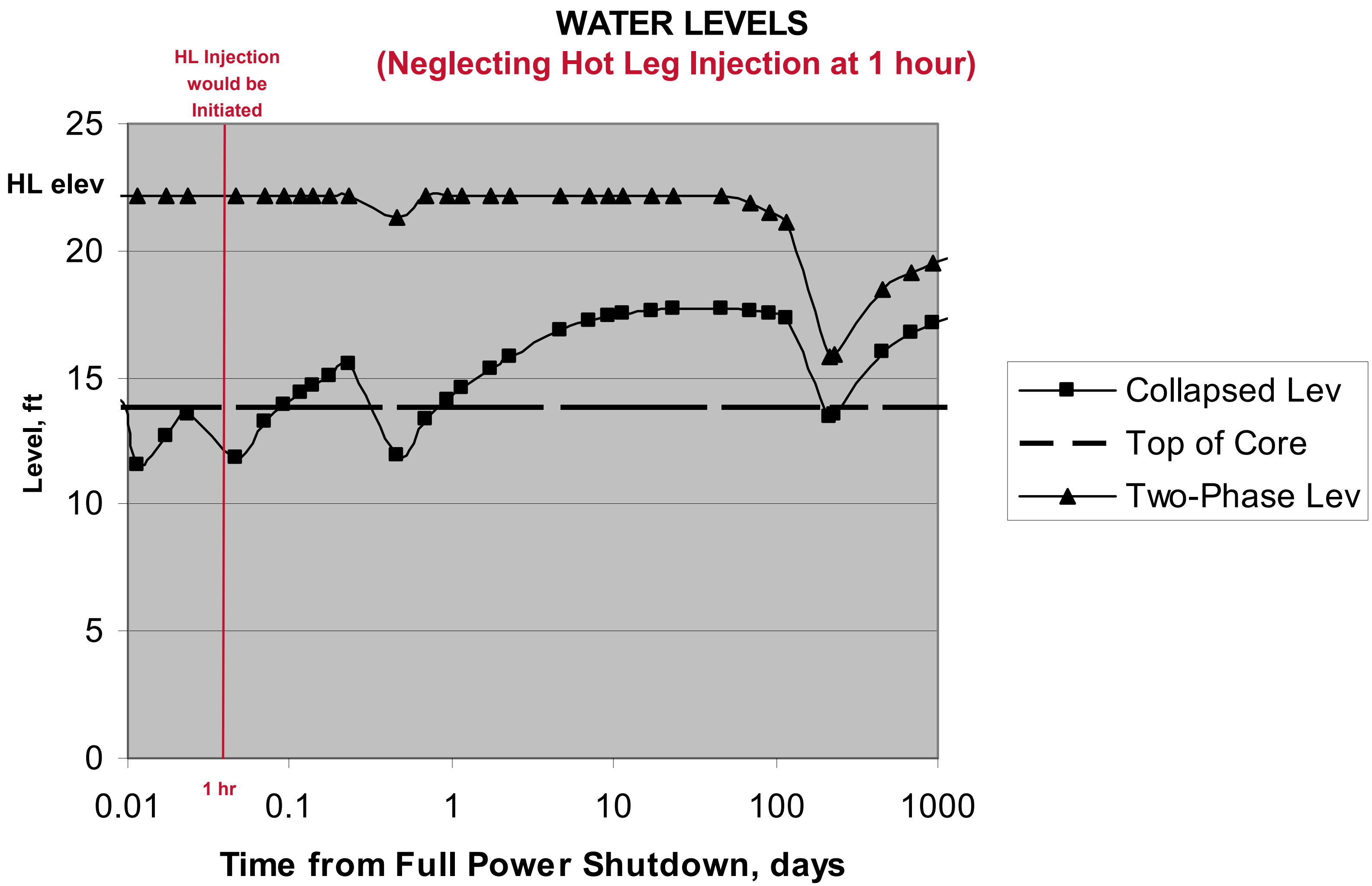
- **Analytical approach**
  - **Quasi-Steady Static-Balance Model**
  - **Primary System is rather quiet with negligible dynamic behavior**
  - **System pressure drops are based on steam flow and hydrostatic heads**
  - **Neglect hot leg injection and boron concentration**

- **Results and conclusion**
  - **Two-phase mixture-level assures long term core cooling**

Long Term Core Mixture Level:
Modeling Concept



Long Term Core Mixture Level:
Typical Result



Long Term Core Mixture Level:
Conclusions

- **Results and conclusions**
  - **Core is covered by two-phase mixture during post-reflood period**
    - High two-phase mixture-level following full power LOCA
    - Modest two-phase mixture-level following low power LOCA
  - **Two-phase mixture-level assures long-term cooling of core**
  - **Shallow EPR loop-seal design Important to results**
    - Top of fuel is only 30 mm below top of loop-seal

Boron Precipitation

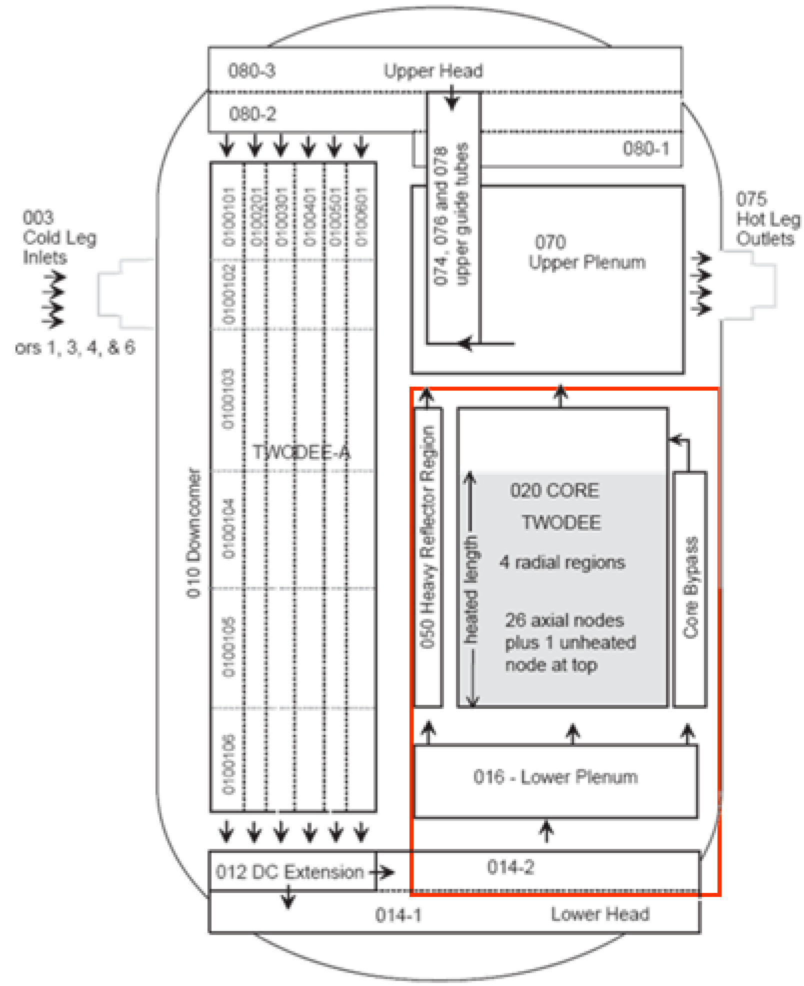
- During the pool boiling phase following a LOCA, boron could concentrate in the reactor core region if countermeasures are not taken. If the concentration of boron reaches the solubility limit, boron precipitates out of solution and potentially causes coolant channel blockage.
- Post-LOCA operator actions include:
  - Continuation of the initial automatic partial cooldown
    - **For small breaks, this results in a depressurization of the RCS, allowing LHSI to refill the RCS and re-establish natural circulation**
  - Redirect >75% of the LHSI to the RCS hot leg at 60 minutes, flushing the core and controlling the concentration
- U.S. EPR uses 37% enriched boron allowing for lower concentrations of boron

Boron Precipitation:
FSAR Analysis

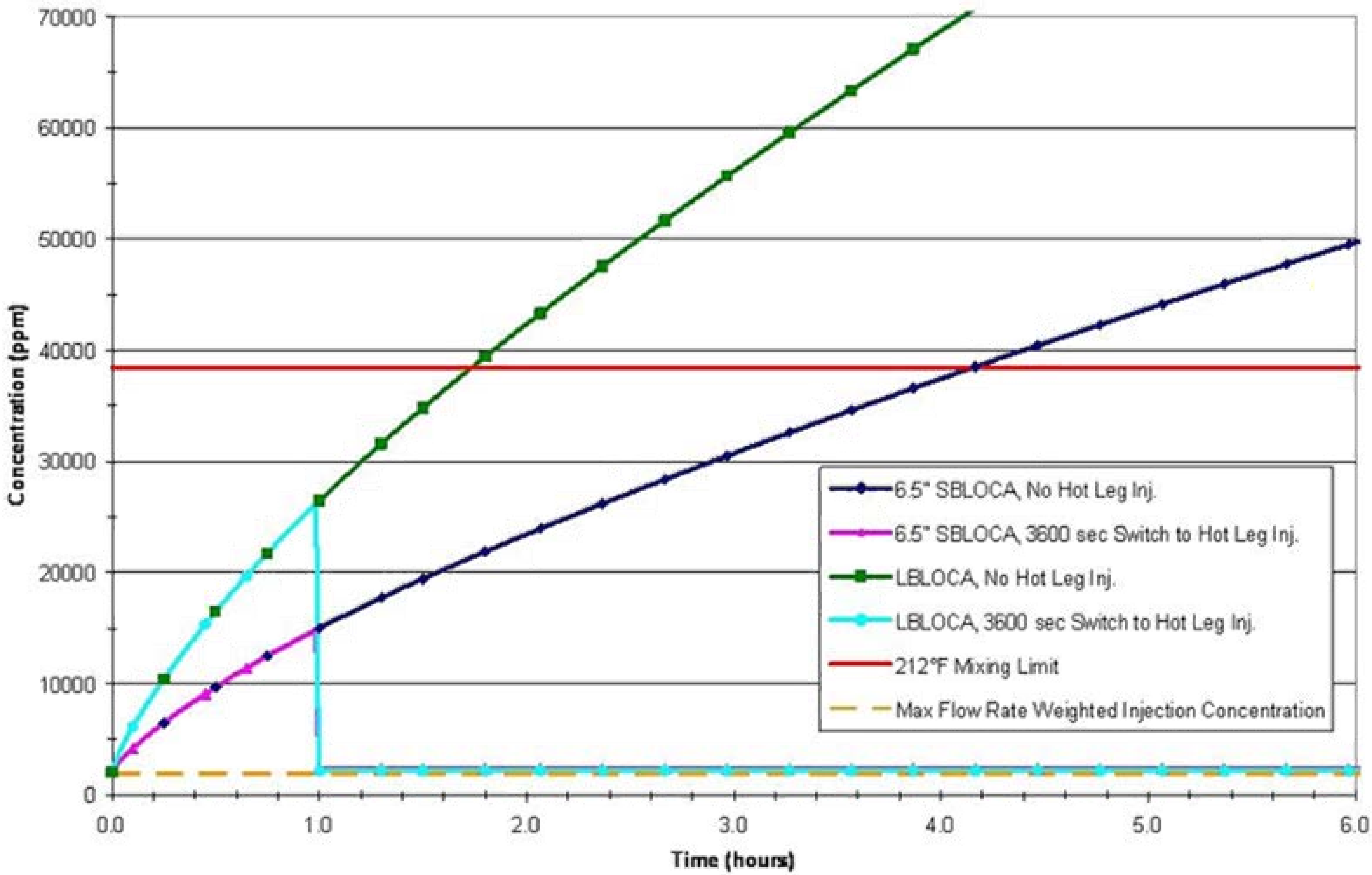
- "Boiling Pot" analysis:
  - Determines the concentration as a function of time resulting from the steaming rate
  - No credit for hot leg injection at 60 minutes
- Key assumptions:
  - Steaming Rate = Latent heat of vaporization at 14.7 psia and ANS 1973 Decay Heat Standard x 1.2
  - No inlet subcooling
  - Injection Rate = Steaming Rate → No increase in liquid volume
  - Injection Concentration = Maximum Flow Rate Weighted Concentration
  - Initial Core Concentration = Injection Concentration
  - No entrainment of boron in steam

Boron Precipitation FSAR Analysis

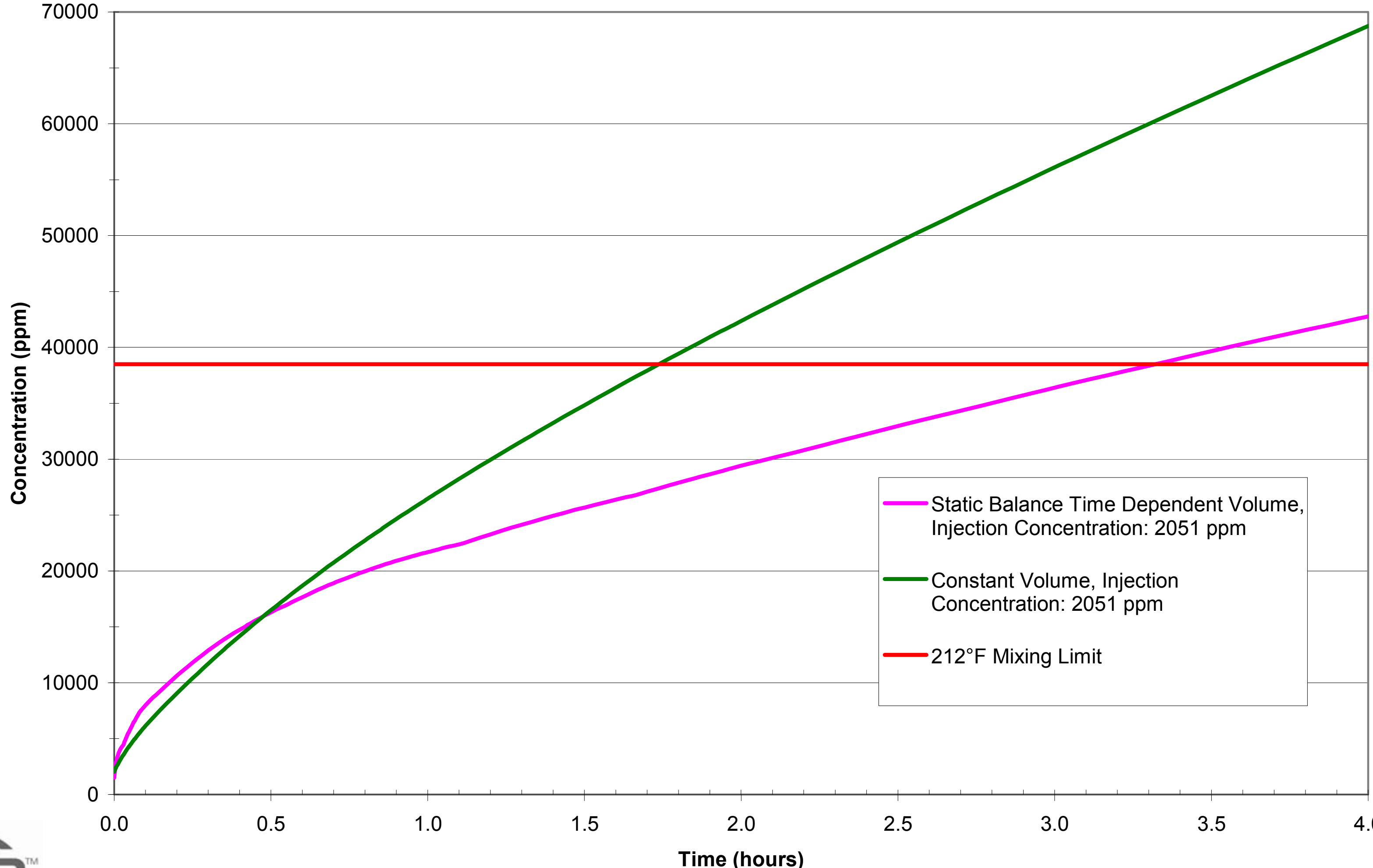
- Concentrating Region is defined as the areas in which core recirculation occurs:
  - Region between lower support plate and active core
  - Active Core
  - Heavy Reflector
  - Guide Tubes
  - Upper plenum up to bottom of hot legs
- Volume at the end of limiting PCT transient – representative of a conservative, post-reflood volume



Boron Precipitation:
FSAR Analysis Results



Boron Precipitation:
Results with Long Term Core Cooling Model



Boron Precipitation:
Conclusions

- For very small breaks the restart of natural circulation prevents the precipitation of boron in the core region
- For larger breaks, hot leg injection redirects >75% of the LHSI at 60 minutes (while maintaining all MHSI and a portion of the LHSI to the cold legs)
- Times to switch to hot leg injection prior to boron precipitation limit:
  - **FSAR Analysis (Constant Volume): 1.74 hours**
  - **Core Mixture Level Model: 3.3 hours**

Nomenclature

CCFL	Counter Current Flow Limit
ECC	Emergency Core Cooling
ECCS	Emergency Core Cooling System
EDG	Emergency Diesel Generator
EFW	Emergency Feedwater
HEM	Homogeneous Equilibrium Model
LBLOCA	Large Break Loss of Coolant Accident
LHSI	Low Head Safety Injection
LOCA	Loss of Coolant Accident
LOOP	Loss of Offsite Power
LPSI	Low Pressure Safety Injection
MFW	Main Feedwater
MHSI	Medium Head Safety Injection
MSRT	Main Steam Relief Train
PCT	Peak Cladding Temperature
RCS	Reactor Cooling System
RHR	Residual Heat Removal
SBLOCA	Small Break Loss of Coolant Accident
SG	Steam Generator
SI	Safety Injection

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Protecting People and the Environment

Presentation to the ACRS Subcommittee

AREVA U.S. EPR Design Certification Application Review

Safety Evaluation Report

Chapter 18: Human Factors Engineering

August 18, 2011

Staff Review Team

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

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    Operator Licensing & Human Performance Branch
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    Operator Licensing & Human Performance Branch
  - **Jacqwan Walker, Technical Reviewer**
    Operator Licensing & Human Performance Branch
  - **Michael Junge, Branch Chief**

    Operator Licensing & Human Performance Branch

- ***Project Managers***
  - **Getachew Tesfaye, Lead Project Manager**
  - **Tanya Ford, Project Manager**

Overview of DC Application

SRP Section/Application Section		No. of Questions	Status Number of OI
18.1	HFE Program Management	21	0
18.2	Operating Experience Review	11	0
18.3	Functional Requirements Analysis and Function Allocation	27	0
18.4	Task Analysis	7	0
18.5	Staffing and Qualifications	13	0
18.6	Human Reliability Analysis	18	0

Overview of DC Application (cont.)

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SRP Section/Application Section		No. of Questions	Status Number of OI
18.7	Human-System Interface Design	36	0
18.8	Procedure Development	13	0
18.9	Training Program Development	2	0
18.10	Verification and Validation	58	0
18.11	Design Implementation	9	0
18.12	Human Performance Monitoring	8	0
Various Sections	Human Factors Engineering	10	0
Totals		**235**	**0**

Objectives

- Outline Staff's Evaluation Process
- Discuss Noteworthy Items of the Review
- Staff Conclusions

HFE Program Review Model

Planning and Analysis	Design	Verification and Validation	Implementation and Operation
HFE Program Management	Human-System Interface Design	Human Factors Verification and Validation	Design Implementation
Operating Experience Review	Procedure Development		Human Performance Monitoring
Functional Requirements Analysis and Function Allocation	Training Program Development		
Task Analysis			
Staffing & Qualification			
Human Reliability Analysis			

Noteworthy Items of the U.S. EPR DC HFE Review

1. Verification and Validation
2. Minimum Inventory
3. Procedures and Training
4. Computer-Based Procedures

Noteworthy Items of the U.S. EPR DC HFE Review – 1

Verification and Validation

- "Robust" treatment of this NUREG-0711 Element
- Detailed Implementation Plan
- Sample of Scenarios

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Noteworthy Items of the U.S. EPR DC HFE Review – 2

Minimum Inventory
(of Alarms, Controls, Displays)

- Description of Development Process for DC
- "List" of specific alarms, controls, displays deferred to COL
- ITAAC item

Noteworthy Items of the U.S. EPR DC HFE Review – 3

Procedures and Training

Both are:

- addressed in SRP Chapter 13
- operational programs
- COL Information Items

Noteworthy Aspects of the U.S. EPR DC HFE Review – 4

Computer-Based Procedures

- General description reviewed as part of the HSI Element
- ITAAC item

U.S. EPR Chapter 18 SER

- No Open Items
- The staff has found the U.S. EPR Chapter 18, "Human Factors Engineering" (FSAR, Tier 2 and associated Implementation Plans) for design certification acceptable.

Acronyms

United States Nuclear Regulatory Commission
Protecting People and the Environment

- COL – Combined License
- DC – Design Certification
- HFE – Human Factors Engineering
- HSI – Human-System Interface
- FSAR – Final Safety Analysis Report
- IP – Implementation Plan
- ITAAC – Inspections, Tests, Analyses, and Acceptance Criteria
- OI – Open Item
- SER – Safety Evaluation Report

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Protecting People and the Environment

Presentation to the ACRS Subcommittee

UniStar Calvert Cliffs Nuclear Power Plant (CCNPP) Unit 3
COL Application Review

Safety Evaluation Report

CHAPTER 15: Transient and Accident Analyses

August 18, 2011

Order of Presentation

- **Surinder Arora** – Calvert Cliffs COLA Lead PM
- **UniStar** – RCOL Applicant
- **Jason Carneal** – Chapter 15 PM
- **Technical Staff**

Major Milestones Chronology

07/13/2007	Part 1 of the COL Application (Partial) submitted
12/14/2007	Part 1, Rev. 1, submitted
03/14/2008	Part 1, Rev. 2, & Part 2 of the Application submitted
06/03/2008	Part 2 of the Application accepted for review (Docketed)
08/01/2008	Revision 3 submitted
03/09/2009	Revision 4 submitted
06/30/2009	Revision 5 submitted
07/14/2009	Initial Review schedule milestones published
09/30/2009	Revision 6 submitted
04/12/2010	Phase 1 review completion milestone
12/20/2010	Revision 7 submitted
August 2011	ACRS Sub Committee review complete on Chapters 2 part 1, 4, 5, 6, 8,10, 11,12, 16, 17 & 19

ACRS Phase 3 Review Plan

FSAR CHAPTERS BY COMPLETION DATES

Chapter(s)	Completion Date	Subcommittee Meeting
8	1/6/2010	2/18/2010
4 5 12 17 19	3/24/2010 3/22/2010 3/19/2010 3/12/2010 4/19/2010	4/20/2010 4/20/2010 4/20/2010 4/20/2010 5/21/2010
10 11 16	6/11/2010 10/30/2010 10/11/2010	11/30/2010
2 (Group 1)	10/29/2010	1/12/2011
6	4/1/2011	4/5/2011
15	7/22/2011	8/18/2011
1, 2 (Group 2), 3, 7, 9, 13, 14, 18	Various	Future meeting dates to be finalized

Technical Staff Review Team

- **Michelle Hart**
  Siting and Accident Consequences Branch
- **Shanlai Lu**
  Reactor Systems, Nuclear Performance, and Code Review Branch

Project Managers:
- **Surinder Arora**
- **Jason Carneal**

Overview of COLA Review

SRP Section/Application Section		No. of Questions	Number of OI
15.0	Transient and Accident Analysis (excepting Section 15.0.3)	0	0
15.0.3	Radiological Consequences of Design Basis Accidents	1	0
Totals*		**1**	**0**

*Note: Totals do not include references to open items in other Sections. Open Item count does not include the Generic Open Item RAI 222, Question 01-5 which was created to track changes to the U.S. EPR Design Certification

Topics of Interest

Section 15.0 – Transient and Accident Analysis

- <u>COL Information Item No. 15.0-1:</u>
- A COL applicant that references the U.S. EPR design certification will provide for staff review, prior to the first cycle of operation, the analysis results demonstrating that the uncompensated DNBR and LPD satisfies the SAFDL with a 95/95 assurance in accordance with ANP-10287P. COL FSAR Section 15.0 states that the analyses results demonstrating that the uncompensated DNBR and LPD satisfies the SAFDL with a 95/95 assurance in accordance with ANP-10287P shall be provided to the NRC staff for review prior to the first cycle of operation.
- <u>Staff Review:</u>
- The staff compared this COL item with the original requirements defined in the safety evaluation report on ANP-10287P. The staff finds that the COL item identified in COL FSAR Section 15.0 is consistent with ANP-10287P. Therefore, the staff finds the identified COL item acceptable.

Topics of Interest

Section 15.0 – Transient and Accident Analysis

- <u>Potential New ITAAC and COL Information Item</u>

- In response to staff RAIs, AREVA has identified the need for COL applicant to provide analysis results demonstrating that the power measurement uncertainty is less than or equal to the estimated value in U.S. EPR FSAR

- These ITAAC and COL items will be required in applicant's COL FSAR submittals in Phase 4

- RAI 222, Question 01-5, which was issued to track changes to the U.S. EPR FSAR and the expected changes to the COL FSAR

Topics of Interest

Section 15.0.3 – Radiological Consequences of Design Basis Accidents

- Review whether appropriate incorporation by reference of the DBA dose analyses from the U.S. EPR FSAR
- Departure to use site-specific short-term atmospheric dispersion factors (χ/Q values) for the low population zone (LPZ)
  - Site-specific doses at the LPZ calculated for all DBAs
    - Show compliance with LPZ dose factor in 10 CFR 52.79(a)(1)
- All other DBA doses incorporated by reference from the FSAR to show compliance with regulatory requirements
  - Exclusion area boundary (EAB) - 10 CFR 52.79(a)(1)
  - Control room - GDC-19
  - Technical support center (TSC) - dose equivalent to GDC-19

Topics of Interest

Section 15.0.3 – Radiological Consequences of Design Basis Accidents

- Staff finding
  - CCNPP 3 COL appropriately incorporated by reference the U.S. EPR FSAR DBA analysis of doses at the EAB, control room and TSC.
    - CCNPP 3 site characteristic χ/Q values for the EAB, control room and TSC are bounded by the values given in U.S. EPR FSAR as site parameters
    - CCNPP 3 DBA doses would be less than U.S. EPR DBA doses
  - U.S. EPR FSAR shows compliance with the EAB, control room and TSC dose factors for all DBAs, therefore CCNPP 3 COL also complies.
  - Site-specific DBA dose results at the LPZ are based on the U.S. EPR FSAR analyses, excepting only the site-specific inputs (CCNPP 3 LPZ χ/Qs) and also meet the 10 CFR 52.79(a)(1) LPZ dose factor.

Acronyms

- COL – combined license
- COLA – combined license application
- DBA – design basis accident
- FSAR – Final Safety Analysis Report
- GDC – General Design Criteria
- IBR – incorporated by reference
- SER – Safety Evaluation Report
- RAI – request for additional information
- RCOL – reference combined license