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Subcommittee on Reliability and  
Probability Risk Assessment

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UNITED STATES OF AMERICA  
NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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MEETING OF THE SUBCOMMITTEE ON  
RELIABILITY AND PROBABILITY RISK ASSESSMENT

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FRIDAY,

JANUARY 24, 2003

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The Subcommittee met at 8:30 a.m. in Room T2B3,  
Two White Flint North, Rockville, Maryland, George  
Apostolakis, Chairman, presiding.

ACRS MEMBERS PRESENT:

- GEORGE APOSTOLAKIS      Chairman
- MARIO V. BONACA          Member
- F. PETER FORD            Member
- THOMAS S. KRESS         Member
- GRAHAM M. LEITCH        Member
- VICTOR H. RANSOM        Member
- STEPHEN L. ROSEN         Member
- JOHN D. SIEBER           Member
- WILLIAM J. SHACK         Member

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NRC STAFF PRESENT:

MEDHAT EL-ZEFTAWY	Designated Federal Official
MICHAEL R. SNODDERLY	Cognizant ACRS Staff Engineer
RICHARD Y. LEE	NRR
ROBERT PALLA	NRR

PRESENTERS:

MICHAEL CORLETTI	Westinghouse
SELIM SANCAKTAR	Westinghouse
JIM SCOBEL	Westinghouse

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A-G-E-N-D-A

**Introduction**

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

8:30 a.m.

CHAIRMAN APOSTOLAKIS: The meeting will now come to order. This is a meeting of the Advisory Committee on Reactor Safeguards, Subcommittee on Reliability and Probabilistic Risk Assessment. I am George Apostolakis, Chairman of the Subcommittee.

Subcommittee members in attendance are Tom Kress, Graham Leitch, William Shack, and Jack Sieber. The purpose of this meeting is to continue to review the PRA provided by the Westinghouse Electric Company in support of its application for certification of the AP1000 design.

The Subcommittee will gather information, analyze relevant issues and facts, and formulate proposed positions and actions as appropriate for deliberation by the full committee. Medhat El-Zeftawy is the designated federal official, and Michael Snodderly is the cognizant ACRS staff engineer for this meeting.

The rules for participation in today's meeting have been announced as part of the notice of this meeting previously published in the Federal Register on December 27, 2002. A transcript of the meeting is being kept and will be made available as

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1 stated in the Federal Register notice.

2 It is requested that speakers first  
3 identify themselves and speak with sufficient clarity  
4 and volume so that they can be readily heard. We have  
5 received no written comments or requests for time to  
6 make oral statements from members of the public  
7 regarding today's meeting.

8 We will now proceed with the meeting and  
9 I call upon Mr. Mike Corletti of Westinghouse to  
10 begin.

11 MR. CORLETTI: Good morning. Thank you,  
12 Dr. Apostolakis. This morning we are going to make a  
13 presentation on Level 2 and 3 PRA. I think we will  
14 probably slightly switch the agenda and talk then  
15 about a brief summary of our results and insights and  
16 then we will go to the phenomenological studies that  
17 we have performed in support of the PRA.

18 Our speaker now is Mr. Jim Scobel. Jim is  
19 our lead on the Level 2 PRA and our phenomenological  
20 studies that we've performed in support of AP1000. He  
21 was also our lead in this area of in-vessel retention  
22 for AP600 as well so he has been with this project for  
23 quite a long time.

24 I just wanted to say that the Level 2 PRA  
25 and the phenomenological studies have been performed

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1 by collaborative effort with Westinghouse. Also with  
2 members of FORDUM which is a Finish utility that has  
3 worked in this area.

4 Also members of Dr. Theofanous at the  
5 University of California, Santa Barbara. Also members  
6 of Foske and Associates which is a Westinghouse  
7 distributor subsidiary, and also members of  
8 Electricite de France, EDF, in France.

9 Jim has led this effort and he's going to  
10 be presenting that later today. I'll turn it over to  
11 Jim.

12 MEMBER SIEBER: Help we out for a second.  
13 That slide is slide 115 in our books?

14 MR. CORLETTI: Yes, sir.

15 MEMBER SIEBER: And the Level 2 PRA in the  
16 original submittal, what page does that start on?

17 MR. CORLETTI: In the PRA?

18 MEMBER SIEBER: Yeah.

19 MR. CORLETTI: Chapter 35 -- 34.

20 MEMBER SIEBER: All right. You may begin  
21 while I hunt.

22 MR. SCOBEL: Good morning. Give me a  
23 second here while I figure out how to work this.

24 MEMBER SIEBER: Scroll.

25 MR. SCOBEL: Okay. For the Level 2 PRA,

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1 like all Level 2 PRAs, we start out with a containment  
2 of entry that we use to quantify the frequency of  
3 events that can happen to the containment during a  
4 severe accident. For the AP1000 containment of entry  
5 we essentially used the same structure of the event  
6 three that we used for the AP600.

7 We actually added a node, therefore,  
8 containment venting. Then we ended up not using it.  
9 The reason for that is that we initially did not  
10 believe that we would have much capability of cooling  
11 the containment with a dry PCS but as we got into the  
12 analyses and we benchmarked the models against the  
13 test data that are codes, then we found that we had a  
14 much better chance of cooling the containment with a  
15 dry PCS than we had originally anticipated. We ended  
16 up not using the venting.

17 Also additionally we improved the  
18 reliability of the water cooling of the PCS by adding  
19 the third diverse line that Terry talked about  
20 yesterday.

21 This is the containment of entry  
22 structure. You can see it's a small containment of  
23 entry. It's got 23 paths on it. We quantify one of  
24 these for each of the accident classes using fault  
25 tree linking techniques for the system nodes. There

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1 are a few phenomenological notes on there as well that  
2 we will cover.

3 We look at different phenomenon, system  
4 availability on the containment of entry. Things that  
5 we are looking at mainly are reactor cooling system  
6 pressure to look at high-pressure core melt phenomena;  
7 containment isolation to see if the containment is  
8 open at the beginning of the accident or not; cavity  
9 flooding specifically for externally cooling the  
10 reactor vessel for IVR; in-vessel reflooding which has  
11 impacts on hydrogen and also in terms of knowing  
12 whether you are cooling the debris from the outside  
13 and the inside of the vessel which is important;  
14 vessel failure; passive containment cooling water;  
15 hydrogen control; containment over temperature which  
16 is a result of disfusion flames at the reactor vessel  
17 walls; hydrogen combustion events such as  
18 deflagrations or detonations; and also, finally,  
19 containment integrity.

20 Operator actions that are specifically  
21 modeled on the tree are several recovery actions to  
22 depressurize the RCS if you have a high-pressure core  
23 melt accident, or to isolate the containment if the  
24 containment has not been isolated automatically by the  
25 systems. And also to actuate PCS water if PCS water

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1 has not been automatically actuated.

2 MEMBER KRESS: How do you have the high  
3 pressure if the AES system doesn't work?

4 MR. SCOBEL: Yeah, you would have to have  
5 a failure of like start-up feed water, ADS passive  
6 RHR.

7 MEMBER KRESS: Pretty low frequency.

8 MR. SCOBEL: Consequently we have a very  
9 low frequency of those events. Also then we include  
10 two severe accident management actions which are  
11 essentially just to flood the cavity to promote IDR  
12 and to actuate hydrogen control.

13 MEMBER LEITCH: I'm a little confused  
14 about containment venting. Is there an operator  
15 action to vent the containment in a severe accident  
16 situation?

17 MR. SCOBEL: We -- no. We have set the  
18 failure probability. We put the note on the tree  
19 initially and then we set the failure probability to  
20 one in the tree. We haven't put anything -- there  
21 actually would be something ad hoc in the SAM-Gs but  
22 there's nothing credited in the PRA.

23 MEMBER LEITCH: But there is the physical  
24 provision to do that, though. I mean --

25 MR. SCOBEL: Yes.

1 MEMBER LEITCH: Okay.

2 MEMBER KRESS: Your success criteria for  
3 butting the reactor cavity, the success of keeping  
4 debris in the vessel.

5 MR. SCOBEL: Yes.

6 MEMBER KRESS: If you flood and if you're  
7 depressurized?

8 MR. SCOBEL: If you flood and if you're  
9 depressurized, yes.

10 MEMBER KRESS: Then your assumption is  
11 yes, the debris never gets into the container.

12 MR. SCOBEL: That's right. And there are  
13 two major assumptions on the containment of entry that  
14 allow us to have such a small containment event tree.  
15 The first one is that if you have a high pressure core  
16 melt accident, that it's going to lead to induced  
17 steam generator tube failure.

18 MEMBER KRESS: What is your basis for  
19 that? Have you run a bunch of calculations to show  
20 that steam generator tube would fail because of filter  
21 and pressure?

22 MR. SCOBEL: It's actually and uncertainty  
23 and we're taking the worst of the paths.

24 MEMBER KRESS: You're saying if you have  
25 this, this gives you the worst consequences?

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1 MR. SCOBEL: Yes. This will lead to --

2 MEMBER KRESS: That's a conservative way  
3 to do the PRA then.

4 MR. SCOBEL: Exactly.

5 MEMBER ROSEN: This is a lot of shorthand.  
6 I would like you to go through the phenomenology of  
7 that first bullet.

8 MR. SCOBEL: The phenomenology?

9 MEMBER ROSEN: Yeah. What exactly  
10 happens?

11 MR. SCOBEL: Okay. I'm sorry. If you  
12 have a high-pressure core melt accident, the core will  
13 -- which is a very rare event in the AP1000 which is  
14 one of the reasons that we take the shortcut, the core  
15 will uncover at high pressure. You will be -- the  
16 primary system will be at the set point of the safety  
17 valve. This is assuming that you have no start-up  
18 feed water, no passive RHR, the core makeup tanks  
19 don't inject, and you don't get ABS.

20 MEMBER ROSEN: Admittedly a very, very low  
21 probability event.

22 MR. SCOBEL: Right. Exactly.

23 MEMBER ROSEN: We can talk about it  
24 anyway.

25 MR. SCOBEL: Okay. That's fine. So the

1 core begins to uncover at high pressure. You have  
2 very strong natural circulation in the primary system  
3 because you have massive steam generators that are  
4 acting as heat sinks, the metal.

5 You know, you've dried out the steam  
6 generators and the metal of the steam generators are  
7 acting as a heat sink. You get strong natural  
8 circulation through the entire RCS. You need to  
9 realize that the AP1000 does not have a loop seal  
10 because of the canned reactor cooling pumps.

11 You get full loop natural circulation in  
12 the primary system which heats up the primary system  
13 very uniformly, as opposed to a current reactor -- a  
14 current generation reactor which has a loop seal which  
15 will heat up the hot legs and the surge line much more  
16 rapidly than it will heat up the steam generator  
17 tubes.

18 As the system heats up, if you look at the  
19 creep rupture characteristics of the hot leg, the  
20 surge line, the steam generator tubes, it becomes a  
21 horse race as to which one is going to fail first.  
22 The steam generator tubes have a bit of an advantage  
23 because they can have a back pressure in the steam  
24 generator that's helping to support them.

25 Because they are also very thin and they

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1 have high hoop stresses, what we see is that it  
2 becomes kind of a 50/50 probability which component  
3 will fail first if you look at this on a current  
4 plant.

5 MEMBER KRESS: And we thought this out.

6 MR. SCOBEL: I'm sure you have.

7 MEMBER KRESS: The assumption has always  
8 been that the hot leg would fail first.

9 MEMBER SHACK: If you had a loop.

10 MEMBER KRESS: If you had a loop. We had  
11 our doubts about --

12 MR. SCOBEL: About the hot leg?

13 MEMBER KRESS: Well, you know, this could  
14 be a probability for distribution. I think this is a  
15 better assumption. On the regulatory side it comes  
16 down as conservative.

17 MR. SCOBEL: Well, I think one reason we  
18 can make this is that we have improved the plant  
19 capability so much in the high-pressure core melt. We  
20 know this is a vulnerability so on the mitigation  
21 side, if you are in this kind of a situation, that  
22 means that you've lost everything so you are making a  
23 lot of assumptions with regard to getting things back  
24 which who knows what you're going to get back and  
25 when. We really put a lot of effort into the

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1 prevention side of the high-pressure core melt  
2 accidents. The second assumption --

3 MEMBER ROSEN: Well, finally what this is  
4 is that the tubes fail.

5 MR. SCOBEL: The tubes fail and you have  
6 a high pressure into the steam generator which can  
7 open safety valve or relief valve and then you have a  
8 direct release to the environment. It goes to  
9 containment bypass, which I remembered to put on the  
10 slide.

11 MEMBER KRESS: You have to put some sort  
12 of source term with that also?

13 MR. SCOBEL: There is a source term  
14 associated with that event, yes. I'll talk about  
15 source terms a little later.

16 The second major assumption is that if you  
17 have a vessel failure and debris relocation into the  
18 containment that immediately results in an early  
19 containment failure. This is a highly conservative  
20 assumption that is -- we can make this because of our  
21 in-vessel retention story being successful.

22 MEMBER KRESS: I agree that is a  
23 conservative assumption. I guess we have to hone in  
24 on questioning it later to look at more detail on your  
25 assumption that it's depressurized and flooding melt

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1 through. That's the first phase in this. There's the  
2 place where there are some questions but that is a  
3 good assumption.

4 MR. SCOBEL: So if you make this  
5 assumption, what it allows you to do is to essentially  
6 eliminate ex-vessel phenomena from the containment.

7 MEMBER KRESS: You still have to calculate  
8 the fuel cooling interactions or whatever. Just  
9 assume it fails for a minute.

10 MR. SCOBEL: Just for fun.

11 MEMBER KRESS: Once again you have to have  
12 source term.

13 MR. SCOBEL: Yes.

14 MEMBER KRESS: I would have to see what  
15 you use for that.

16 MR. SCOBEL: Okay.

17 MEMBER KRESS: Still, that's also very low  
18 frequency.

19 MR. SCOBEL: Yes.

20 MEMBER KRESS: For the same reason.

21 MR. SCOBEL: Interestingly I once looked  
22 at the containment of entry and calculated how many  
23 paths we would have on that 23 path containment of  
24 entry if we didn't have this assumption. It was like  
25 150 so it spans --

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1 MEMBER KRESS: These two phases happened  
2 simultaneously, the same accident sequence?

3 MR. SCOBEL: Typically not. In fact, the  
4 pressurization is the first node on the containment of  
5 entry so if you have a high-pressure accident sequence  
6 --

7 MEMBER KRESS: Failure of the RCS -- I  
8 mean the steam generator tubes, that will  
9 depressurize.

10 MR. SCOBEL: If you fail the steam  
11 generator tubes, it just goes to an end state so you  
12 go then and look at all the other phenomena  
13 associated. It goes to a bypass end state.

14 MEMBER ROSEN: Was the question, Tom, that  
15 if you fail the steam generator tubes, do you also  
16 then fail the vessel?

17 MEMBER KRESS: Yes.

18 MEMBER ROSEN: I don't think you answered  
19 that.

20 MR. SCOBEL: Actually, in the accident  
21 sequence we think about how we model that in the MAAP  
22 code. Actually, it would fail the vessel because you  
23 don't depressurize that much from the -- you would  
24 have to go on -- in the accident sequence you would  
25 have to go on and then probably melt through a hot leg

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1 and model that. Then you would depressurize. That  
2 would be your depressurization mechanism later on in  
3 the accident sequence.

4 MEMBER KRESS: There might be additional  
5 source term with that.

6 MR. SCOBEL: In the end, the source term  
7 for the bypass is so high that any little change --

8 MEMBER KRESS: It doesn't matter.

9 MR. SCOBEL: It doesn't matter.

10 MEMBER KRESS: If you have a high source  
11 term.

12 MR. SCOBEL: Right. Our focus in the PRA  
13 is more oriented not toward fine lining the source  
14 terms, but keeping the containment intact. If you  
15 have an intact containment, your off-site dose is  
16 going to be around 2 rem or less at the site boundary.

17 If you -- it's definitely less than 25 rem  
18 which is our goal. If you fail the containment, it's  
19 definitely above and that includes failure by  
20 containment bypass. Really our focus when we do the  
21 Level 2 PRAs, how do we keep the containment intact  
22 during a severe accident.

23 MEMBER KRESS: And then what sort of leak  
24 rate do you assume?

25 MR. SCOBEL: Design leak rate from the

1 containment. We calculate --

2 MEMBER KRESS: Adjust it for the pressure.

3 MR. SCOBEL: Yes. We calculate a whole  
4 size based on the design leak rate.

5 MEMBER KRESS: Okay. And then use Delta-  
6 B.

7 MR. SCOBEL: Yes. For interface with the  
8 Level 1 PRA we've created a bunch of accident classes  
9 and these are exactly the same accident classes that  
10 we used in the AP600. I use the word accident class  
11 and plant damage state kind of interactively.

12 I would have used the word plant  
13 demonstrate but the accident class came from the  
14 original Italian AP600 PRA that was done in like 1980  
15 whatever it was and it kind of hung around. If I use  
16 the word plant damage state, it kind of means the same  
17 thing.

18 MEMBER KRESS: Those Italians have a funny  
19 way of doing things.

20 MR. SCOBEL: I like to say it's loosely  
21 translated from the original Italian.

22 The accident classes labeled 1 are the  
23 high-pressure accident classes. They include core  
24 damage following a transient such as loss of feed  
25 water or turbine trip or something like that. Core

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1 damage from a small LOCA or an RCS leak with the  
2 passive RHR heat exchanger working.

3 1D is core damage with partial  
4 depressurization of RCS. That one actually becomes so  
5 small that we lump it in with another accident class.  
6 The accident classes labeled 3 are LOCA accident  
7 classes. 3A is an ATWS, anticipated transient without  
8 scram.

9 3BR is core damage following a large LOCA  
10 with full depressurization but you fail the  
11 accumulator so you have a core uncover that is not  
12 recovered fast enough so you get core damage but you  
13 do end up recovering the core eventually.

14 3BE is an accident class where you have a  
15 large LOCA or some kind of a LOCA where you have full  
16 depressurization and you may or may not recover the  
17 core depending on whether the break recovers and you  
18 can get flowback into the break.

19 3BL is core damage following a loss of  
20 recirculation of IRWST water so everything works fine  
21 until you get to gravity recirc. and then you don't  
22 get enough recirculation so long-term cooling fails.

23 3C is core damage following a vessel  
24 rupture which occurs below the elevation of the core  
25 in the vessel so you can't recover the core until you

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1 flood up the containment all the way past the break.

2 MEMBER KRESS: That must be a low  
3 frequency.

4 MR. SCOBEL: You know, it actually shows  
5 up in like the top five dominance sequences because  
6 everything is so low and there is an assumption on the  
7 initiating event frequency. It's kind of a single  
8 note failure cut set.

9 3D is core damage following the LOCA where  
10 instead of having three out of four ADS 4 valves you  
11 have two out of four. Then accidents in Class 6 are  
12 initiated by steam generator tube ruptures.

13 We have all the sequences from the Level  
14 1 PRA are lumped into these accident classes and they  
15 are run through the containment of entry. Just to  
16 give you a feel for the accident class frequencies  
17 from the Level 1 PRA you can see that less than 5  
18 percent fall into the high-pressure accident classes.

19 As you were saying, we do have a very low  
20 frequency of high-pressure core damage. Almost  
21 everything falls into these accident classes which are  
22 depressurized or partially depressurized at least.  
23 Then we have 4 percent probability of having steam  
24 generator tube rupture initiate severe accidents.

25 CHAIRMAN APOSTOLAKIS: Regarding what?

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1 MR. SCOBEL: Yes, sir. This will be an  
2 adventure I haven't done with you. Here we go.

3 CHAIRMAN APOSTOLAKIS: I think in 3BR you  
4 say in the event tree that you don't take credit for  
5 CMTs because they are insufficient. It really is not  
6 a LOCA accumulated event. Right?

7 MR. SCOBEL: That's correct. They don't  
8 inject rapidly enough to cool the core so you get some  
9 -- it's actually fairly minor core damage unless you  
10 make a lot of assumptions on you only have one CMT and  
11 you set the flow rate to the worst possible dimension.

12 CHAIRMAN APOSTOLAKIS: You don't mention  
13 it here. You don't include it in the event tree that  
14 leads to 3BR. Is there any reason or just --

15 MR. SCOBEL: I don't understand the  
16 question.

17 CHAIRMAN APOSTOLAKIS: Why is CMT  
18 mentioned here? In the event tree I don't see a CMT.  
19 It's just accumulator.

20 MR. SCOBEL: Oh, in the Level 1 event  
21 tree?

22 CHAIRMAN APOSTOLAKIS: Yes. Does it make  
23 any difference or is it just something that something  
24 typed in?

25 MR. SCOBEL: Well, they would make -- if

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1 you assume that the CMTs were completely failed, it  
2 would change the accident sequence a bit but you would  
3 still have gravity injection so you would still refill  
4 the vessel. It would just be --

5 CHAIRMAN APOSTOLAKIS: Through the  
6 accumulator.

7 MR. SCOBEL: No, from gravity injection.

8 CHAIRMAN APOSTOLAKIS: When you say  
9 gravity injection, what does it mean?

10 MR. SCOBEL: Gravity injection is from the  
11 IRWST.

12 CHAIRMAN APOSTOLAKIS: Not in this  
13 sequence. For this sequence you go straight to 3BR.  
14 Anyway --

15 MR. SCOBEL: Okay. I see what you're  
16 saying.

17 CHAIRMAN APOSTOLAKIS: The frequency for  
18 this state does not include failure of the CMTs. They  
19 are just complete.

20 MR. SCOBEL: Selim.

21 MR. SANCAKTAR: Selim Sancaktar from  
22 Westinghouse. If you go back and look at the large  
23 LOCA event tree on slide No. 43, you will see that  
24 actually in the ADS we also require CMT. Either  
25 failure of ADS or CMT will cause failure.

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1                   CHAIRMAN APOSTOLAKIS:    The large LOCA  
2 event tree we have doesn't show CMT.

3                   MR. SANCAKTAR:    Look under ADS F.  It says  
4 XADMA.  That is equal to either ADS fails or CMT  
5 fails.

6                   CHAIRMAN APOSTOLAKIS:  3BR, sequence 9, on  
7 the same figure is only large LOCA and failure of the  
8 accumulator.  That is the state we're talking about.

9                   MR. SANCAKTAR:    Okay.  I just wanted to  
10 say that CMT is consistent with the large LOCA.

11                   CHAIRMAN APOSTOLAKIS:  Yeah, but in this  
12 sequence -- look, it may be a trivial matter.

13                   MR. SCOBEL:     I actually understand the  
14 question.  To get the RCS to pressurize, even in a  
15 large LOCA, you have to have full ADS.  To get ADS you  
16 need to have CMTs so what Selim is saying is the CMTs  
17 are inherently in the tree not as their own node but  
18 they are included in considering failure of ADS.  If  
19 you are in 3BR, you are fully depressurized so either  
20 you had CMTs, which is most likely, or the operator  
21 manually initiated ADS.

22                   MR. CORLETTI:    Jim, this is Mike Corletti.  
23 It's because ADS is actuated from the CMT draining.

24                   MR. SCOBEL:     Yes.

25                   MR. CORLETTI:    So we require the CMTs to

1 drain to actuate ADS.

2 MEMBER ROSEN: To automatically actuate.

3 MR. CORLETTI: Yes.

4 MEMBER ROSEN: You can always actuate ADS  
5 manually.

6 MEMBER KRESS: These accident classes you  
7 have include a number of sequences, each one of them.

8 MR. SCOBEL: Yes.

9 MEMBER KRESS: How do you end up getting  
10 the frequency? Do you just add up the frequencies  
11 that follow?

12 MR. SCOBEL: Yes. For the end states of  
13 the containment of entry, we have assigned seven  
14 release categories. The release categories are --  
15 because there are only seven, they are pretty coarsely  
16 defined.

17 They include -- the first one is intact  
18 containment which is a successful severe accident  
19 where you mitigate the accident successfully and  
20 maintain only leakage to the environment. Accident  
21 class BP which, as we discussed earlier, is a  
22 containment bypass typically from steam generator tube  
23 rupture initiated accident or an induced 2 rupture.

24 Containment isolation failure which is a  
25 release that goes through the containment so you get

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1 some attenuation of fission products but then there is  
2 a release of fission products to the environment  
3 through what we consider to be an open HVAC line which  
4 is an 18-inch diameter hole in the containment. Early  
5 containment --

6 MEMBER ROSEN: Is that the biggest line?

7 MR. SCOBEL: That is the biggest line.

8 MEMBER ROSEN: In this plant?

9 MR. SCOBEL: Yes, it is.

10 MEMBER ROSEN: 18-inch.

11 MR. SCOBEL: The 18-inch.

12 MR. CUMMINS: It's the biggest -- this is  
13 Ed Cummins -- that is not a closed system like main  
14 steam or main feed.

15 MEMBER ROSEN: It's the biggest  
16 ventilation one.

17 MR. CUMMINS: Yes.

18 MR. SCOBEL: Then we have early  
19 containment failure. We stuck containment venting in  
20 there because we thought we might need it but then we  
21 didn't need it. It's still there but it has a  
22 frequency of zero.

23 Intermediate containment failure which is  
24 a containment failure which is a containment failure  
25 that occurs after the high energetic core relocation

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1 period of the accident when you are out in time and  
2 the containment becomes well mixed and you fail the  
3 containment but it's prior to 24 hours which is kind  
4 of a magic number, one day after the accident.

5 Then, finally, late containment failures  
6 which would occur after 24 hours. As we discussed  
7 yesterday, actually intermediate containment failure,  
8 late containment failure have very low frequencies.

9 This is a results table from the  
10 quantification of the Level 2. It's listed by --  
11 these are the accident classes that we went through  
12 before and these are the -- that's the core damage  
13 frequency for each of the accident classes. These are  
14 the frequencies for each of the release categories.  
15 Down here, this is the large release frequency.

16 If you look at like intermediate  
17 containment failure, we have numbers in here that are  
18 like 10 to 10th, 10 to the 14th, 13th, 12th. Very low  
19 frequencies. There's not a lot of severe challenge  
20 after the in-vessel core melting and relocation phase  
21 of the accident.

22 Especially considering that we lump all of  
23 the vessel failures into early containment failure.  
24 A lot of your severe challenges that would come  
25 associated with long-term ex-vessel phenomena such as

1 core concrete interaction are already accounted for in  
2 early containment failure. Also, late containment  
3 failure 10 to the 13th, 14th, 15th even. We don't  
4 have a lot of frequency of these CFL and CFI.

5 This number down here for containment  
6 effectiveness, this is like Selim-speak for CCFP,  
7 conditional containment failure probability. It's one  
8 minus the conditional containment failure probability.

9 We presented it in a more positive light  
10 how well did the containment perform. You can see  
11 that for like the LOCA categories we have actually  
12 very good containment performance, 96/97 percent  
13 effectiveness for the containment.

14 Now, 1A sequences. This is high-pressure  
15 core melt. These sequences have a containment  
16 effectiveness of 60 percent so 40 percent would fall  
17 into a category where the operator was able to  
18 recovery the pressurization before the tubes were  
19 threatened.

20 1AP. This is also another high-pressure  
21 category where you would need to look at recovery  
22 actions related to depressurize the containment before  
23 you have a challenge to the steam generator tubes.

24 3A. These are the ATWS accident sequences  
25 and they have a very poor containment performance. In

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1 fact, as you will see later, these are dominant core  
2 damage sequence related to ATWS, or large release  
3 sequences. Also most of our large release is also  
4 tied up in steam generator tube rupture initiated  
5 accidents.

6 MEMBER KRESS: Now, we often counter the  
7 concept of good balance when it's core damage  
8 frequency and given traditional containment failure  
9 probability of .1. How do you extract that condition  
10 out of all of these classes? Do you weigh them by  
11 frequency?

12 MR. SCOBEL: We come up with a large  
13 release frequency compared to the core damage  
14 frequency to --

15 MEMBER KRESS: Well, I'm just looking at  
16 them all, the entire condition of containment failure  
17 probability.

18 MR. SCOBEL: Yes.

19 MEMBER KRESS: That's different than by  
20 general release. You would have to do similar things  
21 being a large release frequency. You just restrict it  
22 to the earlies.

23 MR. SCOBEL: Well, yes, except that our  
24 intermediate and late failures are so small that our  
25 large release frequency and our large early release

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1 frequency are the same number. That's why we just  
2 call it a large release frequency. There's not much  
3 intermediate and late. Our CCFP for this plant is 8  
4 percent which is one minus this number here.

5 MEMBER KRESS: Is that the average of  
6 those things across there?

7 MR. SCOBEL: This here? This is the  
8 containment effectiveness for each of the plant damage  
9 states.

10 CHAIRMAN APOSTOLAKIS: It's one minus a  
11 condition for containment failure.

12 MEMBER KRESS: For that.

13 CHAIRMAN APOSTOLAKIS: For that.

14 MEMBER KRESS: I'm interested in how you  
15 get that.

16 MR. SCOBEL: Well, this would be the large  
17 release frequency for this plant damage state divided  
18 by the core damage frequency.

19 MEMBER KRESS: That's what I was asking,  
20 how you get that number from those numbers.

21 MR. SCOBEL: Yes. So on an individual  
22 basis these are the containment effectiveness numbers  
23 for each. But for the total plant this is the column  
24 here for the overall conditional containment failure  
25 probability. It's 1 minus this number which makes it

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1 8 percent.

2 MEMBER KRESS: That comes out of this  
3 process that you just described.

4 MR. SCOBEL: Yes.

5 CHAIRMAN APOSTOLAKIS: This is the weight  
6 on top of it.

7 MEMBER KRESS: It's a weighted average.  
8 That's what I was trying to get at, how to weight it.

9 CHAIRMAN APOSTOLAKIS: If my goals -- if  
10 I look at option 3 saying that the condition  
11 containment failure probability should be less than 10  
12 percent, obviously you are not meeting that.

13 MR. SCOBEL: No, we are. We have 8  
14 percent.

15 CHAIRMAN APOSTOLAKIS: The interesting  
16 thing, though, is the range of the values there.

17 MR. SCOBEL: These values?

18 CHAIRMAN APOSTOLAKIS: Yes. I mean,  
19 that's the same range that we had in NUREG 1150.

20 MEMBER KRESS: Option 3, remember, groups  
21 things by frequency, though.

22 CHAIRMAN APOSTOLAKIS: But you can choose  
23 everything to go with the core damage frequency in the  
24 condition of containment variable.

25 MEMBER KRESS: For different bins of

1 frequency, though.

2 CHAIRMAN APOSTOLAKIS: Yeah.

3 MEMBER KRESS: They have different  
4 balances. This might fit into that okay. This seems  
5 to put a lot more emphasis on preventing core damage.  
6 If we're looking for a defense in depth balance that  
7 is assigned to option 3, I think this would fit into  
8 it.

9 CHAIRMAN APOSTOLAKIS: You mean satisfy?

10 MEMBER KRESS: Satisfy.

11 CHAIRMAN APOSTOLAKIS: It does.

12 MEMBER KRESS: I mean, even the allocation  
13 to frequency ranges.

14 MEMBER ROSEN: It's very much like what  
15 present day plants are like which is typically 10  
16 percent. Here they have eight.

17 MEMBER KRESS: Typically some of the BWRs  
18 are .8.

19 MEMBER ROSEN: I guess I'm referring to  
20 PWRs.

21 CHAIRMAN APOSTOLAKIS: In terms of  
22 release, which list categories are the worst?

23 MR. SCOBEL: Bypass, BP, and containment  
24 isolation failure.

25 CHAIRMAN APOSTOLAKIS: Which is?

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1 MR. SCOBEL: Bypass is here.

2 CHAIRMAN APOSTOLAKIS: BP.

3 MR. SCOBEL: Bypass is mainly related to  
4 the high pressure 1A.

5 CHAIRMAN APOSTOLAKIS: This is the worst  
6 from the frequency point of view or from the  
7 consequence point of view?

8 MR. SCOBEL: From the consequence point of  
9 view.

10 CHAIRMAN APOSTOLAKIS: So that has 10 to  
11 the -8 frequency. Right?

12 MR. SCOBEL: Yes.

13 CHAIRMAN APOSTOLAKIS: This is almost the  
14 whole thing.

15 MR. SCOBEL: About 54 percent of the large  
16 release.

17 CHAIRMAN APOSTOLAKIS: Of the large  
18 release. Most of it comes from where? From which  
19 plant up state?

20 MR. SCOBEL: Mostly from 6 which is  
21 initiated by steam generator tube failure.

22 CHAIRMAN APOSTOLAKIS: 6 and 3A.

23 MR. SCOBEL: Yeah, they are both the same.

24 MEMBER ROSEN: 3A is inducted?

25 MR. SCOBEL: 3A is ATWS.

1 MEMBER ROSEN: Where is the induced steam  
2 generator tube failure?

3 MR. SCOBEL: 1A. 1A and 1AP together.

4 CHAIRMAN APOSTOLAKIS: So the containment  
5 is doing a pretty bad job protecting you from 3A,  
6 isn't it?

7 MR. SCOBEL: Because it doesn't go through  
8 the containment.

9 MR. SCOBEL: It's actually part of the  
10 problem presenting the results is that the containment  
11 does such a good job that the bypasses all pop way up.  
12 The only way to not have them pop way up is to make  
13 the containment do a worse job.

14 MEMBER SHACK: In your next table we have  
15 the dominant sequences, 3A and 6.

16 MR. SCOBEL: Yes. May I go to the next  
17 table?

18 CHAIRMAN APOSTOLAKIS: Let's go back to  
19 the slide. I'm trying to understand it.

20 MEMBER SIEBER: Nice try.

21 CHAIRMAN APOSTOLAKIS: Plant damage states  
22 for which the containment is doing a good job, the  
23 most frequent ones?

24 MR. SCOBEL: Yes. In fact --

25 CHAIRMAN APOSTOLAKIS: Where do I see

1 that?

2 MR. SCOBEL: Well, you can look at the  
3 containment effectiveness and say this is where the  
4 containment is doing a good job. The ones that are  
5 high, 99, 98, 97. These 3BRs, 3D, 3C.

6 CHAIRMAN APOSTOLAKIS: And these are the  
7 most frequent?

8 MR. SCOBEL: These are -- yeah, we don't  
9 have a --

10 CHAIRMAN APOSTOLAKIS: So what I lose in  
11 the containment is the frequencies lower.

12 MR. SCOBEL: Yes. In fact, if we go back  
13 one more, I think, the ones that were losing the  
14 containment are 6, 1A, 1AP, and 3A.

15 CHAIRMAN APOSTOLAKIS: Okay.

16 MR. SCOBEL: They have a combined  
17 probability of like 8 percent which goes for our 8  
18 percent conditional containment failure probability.  
19 For these sequences are the benign severe accidents,  
20 the LOCA, things that are depressurized.

21 That's one nice thing about this plant.  
22 When you have an accident in which ATS is actuated,  
23 all the accidents tend to look alike because the ADS  
24 system overwhelms the break basically so you know  
25 where the releases come from.

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1           You know where your energy is coming from  
2 driving the containment's natural circulation. You  
3 end up having all these sequences that essentially all  
4 look the same. Some of them are flooded in-vessel and  
5 some of them aren't. That's one difference.

6           Other than that, they are all  
7 depressurized. They are all pretty benign overall in  
8 terms of energy, consequences of their containment.  
9 Then you have these outwires which really have --  
10 we're into one times 10 to the -8 frequency on them.

11           MEMBER ROSEN: I think I know what you  
12 mean by benign in this context but it's not a word I  
13 would chose.

14           MR. SCOBEL: Well, my world is a little  
15 skewed.

16           MEMBER KRESS: Now, the core is a lot like  
17 standard PWR.

18           MR. SCOBEL: Just a little taller.

19           MEMBER KRESS: A little taller. The power  
20 of the level is like 1,000 megawatts of metrical which  
21 is somewhat in the same power level lot that most of  
22 the current plants are. You don't really have to deal  
23 with the fission products here.

24           You're just calculating a large early  
25 release which is really a large -- is when you go to

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1 failed containment early in line so that this large  
2 early release would compare to the NRC acceptance  
3 criteria if they had one.

4 MR. SCOBEL: Yes.

5 MEMBER KRESS: Because it's so much like  
6 the PWRs and their acceptance criteria is based on  
7 current PWRs of that level and sort of a mean of sites  
8 around the country. You don't really deal with  
9 fission products at all.

10 MR. SCOBEL: I'm sorry. I missed the last  
11 sentence.

12 MEMBER KRESS: You're not deal with  
13 fission products at all. You don't really have to  
14 have a source term because your source term is the  
15 same as current plants if you get a large release.

16 MR. SCOBEL: Yes. We do generate a source  
17 term.

18 MEMBER KRESS: Without MAAP?

19 MR. SCOBEL: With MAAP.

20 MEMBER KRESS: It's a close description.  
21 But you don't use it.

22 MR. SCOBEL: Well, we do a Level 3. We do  
23 a site boundary dose.

24 MEMBER KRESS: A Level 3 you've got a site  
25 boundary available?

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1 MR. SCOBEL: Yes. We focus mainly on site  
2 boundary because our goals --

3 MEMBER KRESS: You don't have a site.

4 MR. SCOBEL: Yeah, we don't have a site.  
5 You asked the question yesterday about this. What we  
6 used was the Surrey site with the ocean filled in with  
7 land just to have something. I believe that comes  
8 from URD recommendation for a plant without a site.

9 Do you want to stay here or do you want to  
10 go on?

11 These are the dominant sequences that  
12 contribute to the large release. These top sequences  
13 make up 96 percent of the large release sequences.  
14 You can see that the top two are 3A and 6, the  
15 containment bypass. The first one is from ATWS and  
16 the second one is from steam generator tube rupture.

17 The next two are from vessel failure.  
18 These two are here because of the assumption that if  
19 you don't flood the containment, vessel fails and you  
20 have an early containment failure.

21 The next one is the induced steam  
22 generator tube rupture from the 1A accident. In fact,  
23 down here is the induced steam generator tube  
24 rupture from the 1AP. Here is the vessel failure  
25 initiating event.

1 I kind of like to use this line as a  
2 benchmark because everything that is below here is  
3 less likely than the vessel rupturing falling apart.  
4 It's kind of a way to think about it. There's no  
5 regulation or anything with that but it's just a way  
6 to think about like the rest of the sequences.

7 This sequence is a 3D accident class where  
8 you are partially depressurized and it kind of assumes  
9 that in this partial depressurization it's assuming  
10 you have no stage 4 ADS so you have all your hydrogen  
11 releases through the IRWST and you have a failure of  
12 the vents such that you have a diffusion flame next to  
13 the contaminant wall.

14 Containment isolation failure falls in  
15 down here. Then you start to get into failures from -  
16 - early failures from detonation in the containment.

17 MEMBER SHACK: And your fractions are very  
18 small for all these sequences really.

19 MR. SCOBEL: Yes. The percent of the core  
20 damage frequency for these sequences are all tiny.

21 MR. SNODDERLY: Excuse me, Jim. I see  
22 that we've got about half hour left if we want to stay  
23 on schedule.

24 MR. SCOBEL: Yes.

25 MR. SNODDERLY: So just to keep it in

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1 mind. I know you want to spend probably about a half  
2 hour on the ex-vessel cooling so maybe we could spend  
3 five more minutes on the importance and sensitivity in  
4 the source term and then try to go  
5 to --

6 MR. SCOBEL: Actually, I thought I was  
7 just going to finish up the PRA and then let Selim go.

8 MR. SNODDERLY: Great.

9 MR. SCOBEL: And I'm almost done.

10 MR. SNODDERLY: Okay. Great.

11 MR. SCOBEL: There were sensitivity  
12 analyses that were done also. For example, we didn't  
13 take credit for depressurization in the steam  
14 generator tube rupture case. We had the CCFP went  
15 from 8 to 10.3. We reduced reliability for  
16 containment isolation and doubled the CCFP.

17 Reduced the reliability for hydrogen  
18 ignitors and CCFP went up a little bit. We reduced  
19 reliability for PCS and it hardly went up at all  
20 because PCS is so -- it's actually very reliable. No  
21 credit for pressurization of the high-pressure plant  
22 demonstrates. The CCFP went up to 12.1 percent.

23 Finally, we set the vessel failure  
24 probability to 1. This is with regards to -- for our  
25 vessel failure probability we looked at you could fail

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1 the vessel high up on the vessel and not release  
2 debris of the containment with our assumption that if  
3 you release debris of the containment, you get an  
4 early containment failure. We weren't getting all  
5 early containment failures in 3C. In this we set the  
6 probability of 3C vessel failure to 1. We came up  
7 with 11.8 percent for the CCFP.

8 Finally, for the plant damage states where  
9 you could have large hydrogen releases through the  
10 IRWST, we assumed diffusion flame and detonation  
11 probabilities were 1. Actually, the LRF became pretty  
12 high.

13 It shows that it's a good idea to keep  
14 hydrogen out of the IRWST which seems like a no-  
15 brainer to me. It's a small confined space and you  
16 have fence along the containment wall. It's not a  
17 place where you want to be putting a lot of hydrogen.

18 There was an important analysis where we  
19 set each of the nodal probabilities to 1 and then  
20 looked at how that affected the containment  
21 effectiveness. Obviously if you set containment  
22 isolation failure to 1, you have no containment so RCS  
23 depressurization reduces it a bit but it's only in the  
24 small frequency accident classes.

25 Cavity flooding has a strong impact on

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1 containment failure, especially with respect to our  
2 assumption that if you don't flood the cavity. This  
3 tells you there are some sequences that flood the  
4 cavity inherently.

5 You don't always manually have to flood.  
6 It's kind of a 50/50, 60/40 kind of thing. Those  
7 sequences which show up still as successes are the  
8 ones that automatically flood the cavity.

9 Core reflooding. If you fail core  
10 reflooding, you actually get a little higher  
11 containment effectiveness because there's a hydrogen  
12 impact to flooding the core but it's small. It  
13 doesn't show up all that much because of ignitors and  
14 things like that.

15 Vessel failure has an impact on -- this is  
16 the 3C set to 1. That's the same one we talked about  
17 in the other one. Passive containment cooling. We  
18 have an assumption on the containment of entry that if  
19 you don't have passive containment cooling water, that  
20 you fail the containment in the long term like after  
21 24 hours.

22 That's a conservative assumption. We get  
23 into a realm where we have some probability of  
24 containment failure based on the containment fragility  
25 curve. It's not real high unless you consider -- I'm

1 going to cover this under the phenomena.

2 Unless you consider like you are having a  
3 really bad day like it's 120 degrees outside and the  
4 K heat is the highest that it could possibly be for  
5 the whole time, you will get a containment failure out  
6 in time.

7 Under nominal circumstances you have a  
8 very low containment failure probability. We just  
9 assume that in the long term you have a containment  
10 failure probability of 1 if you don't have passive  
11 containment cooling water. We also have a very  
12 reliable PCS water delivery system so it's a  
13 conservative assumption that's not going to hurt us.

14 Hydrogen ignitors are important to this  
15 plant and have a significant impact on containment  
16 effectiveness as well as diffusion flame. There was  
17 not a lot of impact on just setting the hydrogen  
18 detonation probabilities to 1. This would be because  
19 of the ignitors.

20 MEMBER SHACK: Let me understand. If I  
21 assume a total failure of the passive cooling system,  
22 my LRF is still only 2 times 10 to the -7?

23 MR. SCOBEL: That is the core damage  
24 frequency.

25 MEMBER SHACK: Then you assume it's 1.

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1 MR. SCOBEL: Yes.

2 MEMBER SHACK: How about that.

3 MEMBER ROSEN: Yesterday when I asked  
4 about whether the ignitors were powered during station  
5 blackout from an alternate source, I think the answer  
6 was no. Then there was some discussion about why.

7 MR. SCOBEL: No, they are.

8 MEMBER ROSEN: Here you say they are  
9 important to the plant. I'm a little bit confused  
10 about the power sources to the ignitors.

11 MR. SCOBEL: The ignitors are on AC power  
12 and they are also on batteries. Emergency batteries.  
13 They are nonsafety, non-1E. If you recall, we don't  
14 have a lot of probability in station blackout. I  
15 think station blackout is like .2 percent of the core  
16 damage frequency.

17 Selim, station blackout is something like  
18 .2 percent of core damage frequency?

19 There isn't much station blackout  
20 frequency so loss of power and the ignitors wouldn't  
21 even show up. Especially then in light of the fact  
22 that those are high-pressure core damage sequences and  
23 they most likely go off the containment bypass and  
24 they don't even ask the question about the ignitors.

25 MR. CUMMINS: This is Ed Cummins. Maybe

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1 I can help a little bit here. Yesterday we said that  
2 the batteries that power these last two hours which is  
3 about right because they power other things of  
4 interest like the nonsafety I&C.

5 The other source is AC power in the plant  
6 like the diesels so there's quite a good reliability  
7 for AC power even in the absence of offsite power.

8 MEMBER ROSEN: And the DC power to the  
9 ignitors is rectified. Is converted to AC.

10 MR. CUMMINS: Yes.

11 MR. SCOBEL: So our final large release  
12 frequency is 2 times 10 to the -8, the relayers of the  
13 goal, which is less than 1 times 7 minus 6 per reactor  
14 year. The overall containment effectiveness is 92  
15 percent meaning CCFP is 8 percent.

16 ATWS has the lowest containment  
17 effectiveness and the containment effectiveness for  
18 steam generator tube rupture is 57 percent. If all of  
19 them go to bypass the overall containment  
20 effectiveness, it's still 90 percent.

21 LRF is not sensitive to the reliability of  
22 the hydrogen ignitors, but if the ignitors are assumed  
23 to be failed with a probability of 1, we do have a  
24 significant drop off in containment effectiveness.

25 If the diffusion flame failure probability

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1 is set to 1 for all of the sequences that put a lot of  
2 hydrogen into the IRWST, the containment effectiveness  
3 drops to 85 percent and the LRF increases by a factor  
4 of 4. Controlling hydrogen is a pretty significant --  
5 is a pretty important thing in this plant.

6 In Level 3 we've generated AP1000 specific  
7 source terms with the MAAP 4 code and we used MAX 2,  
8 version 1.12 to calculate offsite doses. Our goal for  
9 the Level 3 was to keep the frequency of the site  
10 boundary dose less than 25 rem at 24 hours and to have  
11 that less than 10 to the -6 per reactor year. This  
12 plot presents the results of --

13 MEMBER ROSEN: What's the EDE stand for?

14 MR. SCOBEL: Effective dose equivalent.

15 From this plot I guess the goal is right about here if  
16 we were to go above this line here.

17 MEMBER KRESS: Is that sort of another  
18 version of release frequency?

19 MR. SCOBEL: Yes.

20 MEMBER ROSEN: So where's -- I'm having  
21 trouble reading this chart. Where is the 25 rem?

22 MR. SCOBEL: I don't actually care for  
23 this plot either. I can say that because I didn't  
24 make it. It would be about right here. It would be  
25 25 rem. 10 to the -6 is right there so on a log scale

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1 --

2 MEMBER SHACK: That's more like 60 or 70  
3 rem, isn't it?

4 MR. SCOBEL: Well, this is a log scale so  
5 that's 1 and that's 100 so 10 is here.

6 MEMBER ROSEN: I don't get anything from  
7 that chart.

8 MEMBER KRESS: That's a frequency  
9 consequence.

10 MEMBER SHACK: I was going to ask you,  
11 Tom. That is so much more enlightening than a CDF and  
12 LRF.

13 MEMBER KRESS: Yeah. It tells me a lot.

14 MR. SCOBEL: I actually put this up for  
15 you.

16 MEMBER KRESS: Thank you.

17 MEMBER SHACK: You're going to explain  
18 this to me later, right?

19 CHAIRMAN APOSTOLAKIS: The frequency of  
20 exceeding 25 rem is 2 or 3 10 to the -7. That's what  
21 he's saying. No more, no less.

22 MEMBER SHACK: If I don't melt the core I  
23 don't get a big release.

24 CHAIRMAN APOSTOLAKIS: That's why it's  
25 flat.

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1 MEMBER SHACK: That's why it's very flat.

2 MR. SCOBEL: Actually, the frequency of  
3 exceeding 25 rem would be the large release frequency  
4 which is 2 times 7 minus 8.

5 CHAIRMAN APOSTOLAKIS: Well, that's not  
6 what you show there.

7 MR. SCOBEL: Well, 25 rem is --

8 CHAIRMAN APOSTOLAKIS: Oh.

9 MR. SCOBEL: This is the core damage.

10 CHAIRMAN APOSTOLAKIS: It can't be up  
11 there.

12 MR. SCOBEL: This is the core damage  
13 frequency.

14 CHAIRMAN APOSTOLAKIS: Okay. Oh. There's  
15 one below which is really flat.

16 MEMBER ROSEN: I'm used to TED. What is  
17 the difference between that and EDE, total effective  
18 dose.

19 MR. SCOBEL: I think it's the same thing.  
20 I think so. I'm not a dose guy.

21 MS. WHITING: This is Erin Whiting from  
22 Westinghouse. Do you have gamma dose included in that  
23 as well as EDE when you get total effective dose  
24 equivalent?

25 MEMBER ROSEN: And so your standard

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1 doesn't include gamma dose?

2 MR. SCOBEL: I think it would. This may  
3 be -- it should say TEDE, I think. We can check on  
4 that. It's probably just --

5 MS. WHITING: This is Erin Whiting.  
6 Usually the gamma dose is not a significant  
7 contributor so they just might have done EDE for a  
8 feel of how it was. Usually it's not a big  
9 contributor to the TEDE.

10 MEMBER ROSEN: But the 25 rem standard is  
11 a TEDE standard. Isn't it?

12 MR. SCOBEL: I believe so, yes.

13 MEMBER ROSEN: So you're only showing part  
14 of it here. Actually you should clear this up some.

15 MR. SCOBEL: Yes. I think we can do that.  
16 I don't think that's a problem. I'm betting -- I'm a  
17 betting man -- that this is a TEDE dose that you would  
18 get from max.

19 MEMBER KRESS: Well, it only shows up in  
20 the design basis accidents anyway, the TEDE. This is  
21 PRA so you can use anything you want. The rules for  
22 TEDE are in the design basis space. I like this plot.

23 CHAIRMAN APOSTOLAKIS: What bothers me the  
24 age of the earth's crust is 3 times 10 to the 9th  
25 years. If you've had one event or one release, you

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1 will get a frequency of 3 times 10 to the -10.

2 MEMBER ROSEN: Assuming AP1000 went into  
3 operation at the same time as the earth's crust was  
4 formed.

5 CHAIRMAN APOSTOLAKIS: Doesn't that make  
6 you stop and think about the meaning of these numbers?

7 MEMBER KRESS: They're kind of hard to --

8 CHAIRMAN APOSTOLAKIS: It's very hard to  
9 swallow that.

10 MEMBER KRESS: -- when they get that low.  
11 The PRA, that's what --

12 CHAIRMAN APOSTOLAKIS: That's right. PRA  
13 came down from the mountain and we had these problems.

14 MR. SCOBEL: What's next?

15 MR. CORLETTI: Mike Corletti. We were  
16 going to have Selim do now a wrap-up of the PRA which  
17 he will just talk about summary of the insights and  
18 also touch on the question that you had yesterday  
19 about how did we explicitly model spurious ADS 4. I  
20 think it won't end the discussion on this but we  
21 wanted while it was fresh in anyone's mind give you  
22 explicitly how it's modeled in our PRA and the basis  
23 for that number.

24 CHAIRMAN APOSTOLAKIS: Very good.

25 MR. SANCAKTAR: My objective here was to

1 wrap this up by showing you some of the results and  
2 insights. In addition to that, if you allow me three  
3 to five minutes, I would like to try to answer one of  
4 the questions that Dr. Rosen asked about how the  
5 reliability of the failure probabilities of the values  
6 assigned.

7 MEMBER ROSEN: Do you have a microphone  
8 on?

9 CHAIRMAN APOSTOLAKIS: You have to put it  
10 on your tie. Oh, it's not on at all? That's the  
11 first thing you have to do.

12 MR. SANCAKTAR: Is that better?

13 CHAIRMAN APOSTOLAKIS: Put it on your tie.

14 MR. SANCAKTAR: Okay.

15 CHAIRMAN APOSTOLAKIS: High.

16 MR. SANCAKTAR: Okay. How's this?

17 CHAIRMAN APOSTOLAKIS: How you're wired.

18 MR. SANCAKTAR: Okay. Shall I repeat what  
19 I said before?

20 MEMBER ROSEN: Yes.

21 MEMBER KRESS: You don't have to. We  
22 heard you.

23 CHAIRMAN APOSTOLAKIS: Don't do it then.

24 MR. SANCAKTAR: This slide was shown  
25 yesterday also. It's the same slide I showed

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1 yesterday. This just kind of shows the relation  
2 between AP600 and AP1000. It compares the numerical  
3 results and also shows the areas where analyses were  
4 performed.

5 Basically the very first observation we  
6 have is the low risk of AP600 has been also retained  
7 in AP1000. We also acknowledge that there was an  
8 increase in core damage frequency as reported before.  
9 Some of it was actually reduced by changing the  
10 success factor here. Safety goals are met, of course.

11 CHAIRMAN APOSTOLAKIS: With significant  
12 margin?

13 MR. SANCAKTAR: With significant margin.

14 CHAIRMAN APOSTOLAKIS: How do you know  
15 that?

16 MR. SANCAKTAR: According to the numbers,  
17 mean values of whatever you want to call it. We can  
18 argue about what those numbers mean, uncertainties and  
19 so on.

20 CHAIRMAN APOSTOLAKIS: You have only  
21 included parameter of uncertainty which is really  
22 relevant. You really believe it's a factor of 6?

23 MR. SANCAKTAR: Yeah.

24 CHAIRMAN APOSTOLAKIS: Something that has  
25 never been built and you are claiming 10 to the -7

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1 core damage frequency. You can only be uncertain by  
2 a factor of 6?

3 MR. SANCAKTAR: Six. We discussed this a  
4 little bit yesterday. Who was there? Oh, you were  
5 there. Let me mention this for your information. We  
6 have clearly stated in our data analysis that we are  
7 going to be using mean values and anything that is a  
8 mean value, anything we think.

9 CHAIRMAN APOSTOLAKIS: Converted to that.

10 MR. SANCAKTAR: Converted.

11 CHAIRMAN APOSTOLAKIS: That's not what the  
12 issue is.

13 MR. SANCAKTAR: Once we converted it to a  
14 mean value, those results hold. Now, we can go back  
15 one step and say were they really mean values or  
16 medium values. That's a different issue.

17 CHAIRMAN APOSTOLAKIS: That's not the  
18 issue. The issue is there are so many models have  
19 gone through this. Human performance, failures and so  
20 on. Why is the number there? It comes from the  
21 utility documents so nature is going to say, "Gee,  
22 it's in every document. I'd better comply."

23 Then what I'm doing is I'm looking back at  
24 the LWR and I'm seeing the numbers going all over the  
25 place as we learn more with more experience. I think

1 it's an under estimate. I'm not saying that the  
2 changes are based on conclusions but I think saying  
3 that you're meeting the goals with significant margin  
4 is pushing it a little bit. You just don't know. I  
5 don't know. You may be right but I don't know.

6 MR. SANCAKTAR: The point is, I agree with  
7 you philosophically. However, in a world of practical  
8 decision making we have to hold it to that line and  
9 explain the reasons behind it and so on. Otherwise,  
10 I agree with you. Then I could make the same argument  
11 about anything.

12 I'm not certain about many other things  
13 and I can go back and talk about 10 to the -5 and 10  
14 to the -4 and we can talk endlessly because there is  
15 no decision making factor defined by anybody. Nobody  
16 has said that you should meet by 99 percentile  
17 confidence. There is nothing to meet. We have to at  
18 some point define it, draw the line.

19 MEMBER ROSEN: I understand the pragmatics  
20 of it but to reinforce what George is saying, when we  
21 talk about current day operating plants that have been  
22 operating for a significant period of time, we're  
23 talking about uncertainties that are larger than a  
24 factor of 6 typically like an order of magnitude.

25 MEMBER KRESS: According to what?

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1                   MEMBER ROSEN:   Not by 1150.   I'm just  
2 saying when we propagate uncertainty through these  
3 analyses, we come up with an answer that says a factor  
4 of 10.

5                   MR. SANCAKTAR:   If it makes you feel more  
6 comfortable, we can do that for you.

7                   MEMBER ROSEN:   It doesn't make me more  
8 comfortable. All it says is that these things -- this  
9 plant certainly -- the uncertainty in this plant's  
10 analysis cannot be smaller than the uncertainty and  
11 the analysis of plants that have been built and run  
12 for a long time.

13                   CHAIRMAN APOSTOLAKIS:   Selim, one of the  
14 goals of this agency is building public confidence.  
15 I don't think that by saying that it's a factor of 6  
16 we are contributing to that. Why don't you go ahead.

17                   MR. SANCAKTAR:   So, where were we? The  
18 total plant severe release frequency is another order  
19 of magnitude -- this was just discussed a few minutes  
20 ago. We discussed this a little bit yesterday,  
21 internal flooding.

22                   MEMBER ROSEN:   I don't understand why  
23 you're going over this again.

24                   MR. SANCAKTAR:   I don't know honestly. I  
25 agree with you.

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1 CHAIRMAN APOSTOLAKIS: You're supposed to  
2 talk about the reliability of the valves. Go ahead.

3 MR. SANCAKTAR: Thank you. I guess this  
4 was a request for whoever it is, not here, something  
5 to present to wrap up.

6 CHAIRMAN APOSTOLAKIS: Repetition is one  
7 way of making people understand something.

8 MEMBER KRESS: Tell them what you're going  
9 to say and say it.

10 MR. SANCAKTAR: Thank you very much.  
11 These are not necessarily my slides. I'm just trying  
12 to repeat.

13 Dr. Rosen asked about how the failure  
14 problem of explosive valves were assigned so I wanted  
15 to quickly tell you what the number is, where we got  
16 it from. These are pages that I photocopied from our  
17 submittal to the NRC PRA. If you want, I can give it  
18 to you officially or unofficially, whatever is  
19 easiest. Or I can just mention to you which page it  
20 is and you can just read it.

21 I'm looking at page 8, section 32, data  
22 analysis section. There's a table there that says  
23 explosive valves, failure to operate. Mean value on  
24 demand is 5.8 10 to the -4. It says, "Remark - See  
25 note from Priscilla" which appears on page 32-20.

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1           This very clearly indicates what we did  
2           which I will summarize to you. The URD document had  
3           an explosive valve failure probability on demand of 3  
4           times 10 to the -3. It is the general consensus of  
5           people who use these valves that they are very  
6           reliable. I mean, that number really is not  
7           representative of the valve liability.

8           That was the general consensus because  
9           it's higher reliability than that. Where did this  
10          number come from, the 3 times 10 to the -3, that went  
11          into the URD? I don't know but I can guess because 3  
12          times 10 to the -3 immediately reminds me of the NUREG  
13          1150 where the valves were assigned 3 times 10 to the  
14          -3 failure probability. I'm not saying this is a fact  
15          but I'm surmising that might have just been used  
16          across the board without really considering the  
17          characteristics currently used explosive valve.

18          What we did was we went to Sandia  
19          Laboratories and we asked them. We said, "Do you have  
20          experience with explosive valves?" They have lots of  
21          experience. We're not talking about 10 hours or 100  
22          hours. We are talking about a 100,000 hours of  
23          experience.

24          Two difference departments of Sandia  
25          Laboratories sent us letters back in writing. They

1 gave us their data, number of hours, number of  
2 failures. From that we obtained two different values,  
3 two more values. We have one number that the URD gave  
4 us. We didn't throw it away but it is kind of  
5 suspicious.

6 If it is this unreliable, why are people  
7 saying this is a reliable valve and they are using it?  
8 It just doesn't jive if it has the same failure  
9 probability as MOV. It just doesn't make sense other  
10 than the fact that somebody picked it up and plugged  
11 it in there.

12 The bottom line -- I'm about to finish --  
13 we got two letters in writing from two different  
14 departments of the Sandia Laboratories with total  
15 mission times of 10s and 100s of thousands of hours.  
16 From that there were two more numbers. One was 2  
17 times 10 to the -4 and the other one was 3.2 times 10  
18 to the -4. We now have three numbers.

19 MEMBER ROSEN: What number did you use  
20 again since I don't have it in front of me? Five  
21 times 10 to the -4?

22 MR. SANCAKTAR: Right.

23 MEMBER KRESS: Average.

24 MR. SANCAKTAR: We have three numbers now.  
25 We don't know which one is right and which one is

1 wrong. We don't want to pass judgement on it so we  
2 checked with three experts. They gave us three  
3 different numbers. We too a geometric average of the  
4 three numbers and we came up with a number 5.8 times  
5 10 to the -4. We don't anything else. We don't have  
6 our own tests. We don't have any magic numbers. We  
7 just looked around for --

8 MEMBER ROSEN: I've never tested them. So  
9 you're using the Sandia numbers. Okay. Now, that  
10 helps because what I thought you were doing was using  
11 the BWR numbers. The BWR numbers are clearly not  
12 applicable to a 14-inch valve.

13 Now, we have Sandia giving you two numbers  
14 which in those letters, which I haven't seen but I  
15 believe you, say they are applicable to the 14-inch  
16 valve. Can we get some further assurance of that?

17 MR. SANCAKTAR: That, I think, we will try  
18 to give you that assurance in our next meeting. I  
19 just wanted to give you facts as it existed today what  
20 we did and then we'll go to the next stage.

21 MEMBER ROSEN: Selim, I wouldn't pester  
22 you if it weren't so important.

23 MR. SANCAKTAR: Okay.

24 MEMBER ROSEN: The central issue of ADS as  
25 a safety function in this plant.

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1 MR. SANCAKTAR: Certainly.

2 MR. CORLETTI: This is Mike Corletti.  
3 While it was fresh in our minds we wanted to give you  
4 what we did use. I think we would plan at the plant  
5 meeting we would have to provide a better presentation  
6 of the valves and the history.

7 MEMBER ROSEN: I worry you might get into  
8 some classified stuff with Sandia. What I would like  
9 to see is the numbers that -- you know, backup to  
10 those letters, what kind of valves are they, and make  
11 the case that the things they have actually tested.  
12 They have a lot of experience and tell me what the  
13 experience is. Show me the construction of the  
14 valves. Make me comfortable that the ones they use  
15 are like this one and in the same size range.

16 MEMBER SHACK: Isn't the case really here  
17 whether the charge goes off? I mean, you can do the  
18 analysis for the rest of it in a believable way.

19 MEMBER ROSEN: I thought that for a while  
20 and then I looked at these valves and I worried that  
21 the charge might go off and the piston might not go  
22 down. Charge goes off, bang, and the piston sits  
23 right where it is because it's cocked and it never  
24 separates.

25 MEMBER SHACK: This is a valve that sits

1 on a noncorrosive environment. It's not going to bind  
2 up, build corrosion products. You're not going to  
3 find a whole lot of testing experience on these  
4 valves. I can guarantee you that.

5 MEMBER ROSEN: That's what worries me.

6 MR. CUMMINS: This is Ed Cummins. We  
7 agreed yesterday to provide more information. I'm not  
8 sure the level of the more information will satisfy  
9 you so we won't prejudge the next meeting. But  
10 certainly we'll bring the expertise that we can find  
11 to discuss the topic.

12 MEMBER ROSEN: Given the importance, I  
13 don't think I'm ever going to be satisfied until I see  
14 the valve built, you put 10 of them up there and you  
15 go --

16 MEMBER SHACK: Yeah, but 5 times 10 to the  
17 -4 you're going to be testing a lot of valves.

18 MEMBER ROSEN: I know. I know, but at  
19 least phenomenologically --

20 MEMBER SHACK: But I'll sign up for the  
21 contract.

22 MEMBER KRESS: You don't have to attach 10  
23 to the four of them. You can use statistical.

24 MEMBER ROSEN: I am a hands-on plant kind  
25 of guy. I like to see things that are supposed to

1 work work. And then I can get some familiarity with  
2 how they work. And then when I'm comfortable that  
3 they work, I'm comfortable. Right now we're just  
4 talking about data and analysis, and that's  
5 interesting but the closer you can get to the ideal,  
6 I know you can never achieve it but I want to hear  
7 more about that.

8 MEMBER SHACK: That's a binomial  
9 probability, Tom. If I want a 95 percent confidence  
10 on that binomial probability, I'm going to be doing a  
11 lot of testing.

12 MEMBER KRESS: Oh, yeah. It's about twice  
13 the number. It's like twice of -- the inverse of 1 on  
14 10 to the -4. But that's a lot of math. But you're  
15 never going to get that and we've got to rely on what  
16 we've got, I think, in this case.

17 We would have to make a judgement on the  
18 Sandia data or a calculation, so I don't think you're  
19 ever going to achieve a reliability out of testing  
20 these. It's not going to happen. So we have to make  
21 our judgments on what we've got, I think.

22 Now the other question that I have is that  
23 the new Westinghouse logo?

24 MR. SANCAKTAR: Yes.

25 MEMBER ROSEN: Are you done Selim?

1 MR. SANCAKTAR: Yeah, I'm done.

2 MEMBER KRESS: Thank you. I don't think  
3 you should have averaged in the utility requirements  
4 document number. You should have gave me a higher  
5 number.

6 MR. SANCAKTAR: We don't trust that number  
7 but we thought if we leave it out, we will have even  
8 more headaches than we would otherwise.

9 MEMBER ROSEN: Now we have a discussion of  
10 in-vessel retention of molten core debris scheduled to  
11 be complete by our break at 10:05. I don't think so.

12 MEMBER KRESS: You want to take a break  
13 now?

14 MEMBER ROSEN: I think so. That would  
15 make more sense. Our break was supposed to have been  
16 a 25-minute break. Let's get back here by 10:25.  
17 10:20 would be good enough.

18 (Whereupon, off the record.)

19 MEMBER ROSEN: All right. We are back in  
20 session.

21 MR. SCOBEL: Okay. I am going to talk  
22 about what we've done for in-vessel retention for the  
23 AP1000. Just a little run-through for anybody who  
24 doesn't have a strong background in in-vessel  
25 retention, the phenomena that we're talking about is

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1 maintaining molten-core debris in the lower head of  
2 the reactor vessel by externally cooling the outer  
3 surface of the reactor vessel with water.

4 The AP1000, like the AP600, is able to  
5 flood the reactor cavity above the loop nozzles of the  
6 reactor vessel. If you get core debris in the lower  
7 plenum of the reactor vessel and you boil the water on  
8 the outside of the reactor vessel and cool the outer  
9 surface of the vessel, the vessel doesn't fail and the  
10 debris is maintained inside without then being  
11 relocated to the containment and causing problems like  
12 core concrete interaction or ex-vessel steam  
13 explosion, that sort of thing.

14 MEMBER ROSEN: We worry about departure  
15 from nuclear boiling in a lot of places. This is one  
16 of them. Are you going to talk about that?

17 MR. SCOBEL: Yes.

18 MEMBER KRESS: The cartoon that you have  
19 there shows two layers stratified.

20 MR. SCOBEL: Yes.

21 MEMBER KRESS: How do you know that's what  
22 is going to happen?

23 MR. SCOBEL: Based on the melt relocation  
24 phenomena, which I'll get into a little later, what  
25 you end up with is oxide debris filling up the lower

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1 plenum and contacting the metal debris from the bottom  
2 allowing the metal debris to then melt on top of the  
3 oxide debris with a crust in between.

4 MEMBER KRESS: In a core melt accident  
5 don't metal phases generally melt first?

6 MR. SCOBEL: They do but they refreeze at  
7 the bottom of the -- at the bottom of the core there's  
8 a lot of volume there. I am going to kind of get into  
9 in-vessel melt relocation. I'll continue and then  
10 we'll go there.

11 The AP1000 has a bunch of reliable plant  
12 features that promote in-vessel retention, the first  
13 of which is post-accident reactor cooling system  
14 depressurization which reduces the stresses on the  
15 reactor vessel if you have debris in the lower head.  
16 You will weaken the lower head and think it  
17 significantly so you really need to be depressurized  
18 for this to be successful.

19 There are no lower head penetrations in  
20 the reactor vessel. The only failure mechanism  
21 basically is creep failure of the lower head. The  
22 reactor vessel is submerged in water post-accident  
23 which is either automatically by the progression of  
24 the accident or the operator has the ability to  
25 manually flood and fill up the cavity.

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1           The lower support plate sits very low in  
2 the lower plenum. Therefore, the lower plenum debris  
3 that fills up in the lower plenum can contact and melt  
4 the lower support plate on top of the debris. This  
5 creates a thick metal layer on top of the debris and  
6 it mitigates something that is called the focusing  
7 effect of heat transfer where the heat that is  
8 transferred from the oxide layer into the metal layer  
9 is spread out over a larger area of the reactor vessel  
10 by the thick metal layer.

11           Also we have reactor vessel insulation  
12 that is designed to allow water to come in contact  
13 with the outside surface of the reactor vessel and to  
14 vent steam from the top of the insulation. There's an  
15 annulus between the reactor vessel and the insulation.

16           I have a cartoon. First of all, this is  
17 a containment flooding. You've seen this picture  
18 before. When the water from the IRWST is drained into  
19 the containment it fills up what we call the floodable  
20 region of the containment and will fill up above the  
21 loop elevations. You can see the ADS stage 4 sticks  
22 up like a snorkel above the water level. In IVR  
23 configuration this would be the successful containment  
24 flooding configuration.

25           This is a cartoon of reactor vessel

1 insulation that promotes IVR. There's an inlet at the  
2 bottom that is designed to normally be sealed for  
3 normal operation. You have complete insulation but  
4 when you flood up, it allows water to come in through  
5 the bottom.

6 It forms a baffle around the lower head  
7 that channels the flow. At the top there are vents  
8 designed that go through the concrete and vent up into  
9 the nozzle gallery near the reactor vessel loops.

10 MEMBER ROSEN: This cartoon looks like  
11 it's some sort of toilet bowl float. Is that what it  
12 is?

13 MEMBER SIEBER: Yeah, a float valve.

14 MR. SCOBEL: There is a design on paper  
15 that has like float valves. There's a whole bunch of  
16 them. It gets kicked around to change that design to  
17 something.

18 MEMBER ROSEN: What do you mean it gets  
19 kicked around?

20 MR. CUMMINS: This is Ed Cummins. We  
21 don't claim to have the detailed design of the valve  
22 but the concept of the valve is that it must passively  
23 open when water comes in to make it float. The  
24 current one is a bunch of float balls and then the  
25 detailed design is a COL item actually.

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1 MEMBER ROSEN: But normally it's sealed so  
2 there is no air flow through there.

3 MR. CUMMINS: Exactly. You want the  
4 cooling air to go up to the vessel supports.

5 MR. SCOBEL: In normal circumstances the  
6 top of these vents is covered and the bottom is  
7 sealed.

8 MEMBER KRESS: What is the general size of  
9 that annulus?

10 MR. SCOBEL: It's 6 to 9 inches, I  
11 believe.

12 MEMBER ROSEN: And how do you get the tops  
13 off? I understand how you are thinking about getting  
14 the bottom open but how do you get the tops to seal  
15 the tops off?

16 MR. SCOBEL: They just sit on top of the  
17 vent.

18 MEMBER ROSEN: So they don't come off when  
19 you go to in-vessel retention?

20 MR. SCOBEL: They do. You get a lot of  
21 steam and water flow up through there which is --

22 MEMBER ROSEN: So it pops them off.

23 MR. SCOBEL: Pops them off.

24 MEMBER SIEBER: What would happen if you  
25 didn't have anything and it was just open?

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1 MR. SCOBEL: You wouldn't want it to be  
2 open because of the insulation. You get a lot of heat  
3 from the reactor vessel that would be coming up  
4 through there.

5 MR. CUMMINS: This is Ed Cummins. The way  
6 we cool the reactor vessel support is by blowing air  
7 into that cavity. It goes up on the outside of the  
8 insulation and comes up and cools the vessel supports.  
9 You need to do that to keep the concrete less than 200  
10 degrees.

11 MEMBER SIEBER: Okay.

12 MEMBER KRESS: And am I looking at the top  
13 at an annulus that goes around, or am I looking at a  
14 couple of pipes?

15 MR. SCOBEL: There are four of these.

16 MEMBER KRESS: Four of these?

17 MR. SCOBEL: Yes.

18 MEMBER KRESS: Okay. So this annulus  
19 funnels itself into four.

20 MR. SCOBEL: Yes.

21 MEMBER KRESS: Located 90 degrees apart.

22 MR. SCOBEL: Yes.

23 MEMBER ROSEN: Kind of like Rogers.

24 MEMBER KRESS: Has that configuration been  
25 tested somewhere?

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1 MR. SCOBEL: Yes, it has actually.

2 MEMBER KRESS: ROSPLOT?

3 MR. SCOBEL: No, ULPU. For the AP600 we  
4 performed risk oriented accident analysis by Professor  
5 Theofanous for our IVR assessment. It was presented  
6 in DOE report. There was an analysis and a test  
7 program and a peer review associated with this  
8 analysis. From this analysis there were two tests  
9 that were done.

10 The first was ACOPO which looked at the  
11 natural convection of the debris inside the reactor  
12 vessel and the way the heat transfer was partitioned  
13 in the oxide layer. And ULPU which was a test to  
14 investigate critical heat flux capability on the  
15 outside surface of the reactor vessel lower head.

16 From that report and investigation of  
17 AP600 we found that the limiting vessel failure  
18 criterion was DNB basically, departure from nuclear  
19 boiling. Exceeding the critical heat flux, or keeping  
20 the heat flux to the vessel wall from the debris less  
21 than the critical heat flux is our success criteria.

22 Also the steady state two-layer debris  
23 configuration presented the limiting challenge to the  
24 reactor vessel. I should say the credible limiting  
25 challenge to the reactor vessel which was a metal over

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1 oxide debris bed configuration in the lower plenum.

2 And AP600 showed a very large vessel  
3 failure actually. We had about a 50 percent -- 50 or  
4 60 percent -- the heat transfer to the vessel wall was  
5 about 50 to 60 percent of the critical heat flux for  
6 AP600. With the cavity flooded and the RCS  
7 depressurized we had success.

8 MEMBER KRESS: Did the metal layer in  
9 these tests have any heat source other than from the  
10 oxide?

11 MR. SCOBEL: No, it was all from the  
12 oxide. It was considered to be in the oxide.

13 MEMBER KRESS: The heaters were put into  
14 the oxide?

15 MR. SCOBEL: No. The ACOPO test. The  
16 natural circulation of the ACOPO test was actually  
17 done on kind of a cool-down basis.

18 MEMBER KRESS: Hot debris in the first  
19 place?

20 MR. SCOBEL: No. It was done with freon.  
21 Water and freon. The purpose of the test was to look  
22 at the heat fluxes to the vessel wall.

23 MEMBER ROSEN: Does the surface of the  
24 bottom of the vessel outside matter --

25 MR. SCOBEL: Yes.

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1 MEMBER ROSEN: -- what the condition is?

2 MR. SCOBEL: Yes. It does matter.  
3 Especially for AP1000.

4 MEMBER ROSEN: Can you tell us more about  
5 what you are requiring?

6 MR. SCOBEL: Talk about AP1000 versus  
7 AP600. The designs are similar but there are changes  
8 between the designs that impact us. The first is that  
9 we have the taller core with 157 14-foot fuel  
10 assemblies instead of 145 12-foot fuel assemblies and  
11 the power level is increased from 1,933 megawatts up  
12 to 3,400 megawatts.

13 We have a core shroud instead of a core  
14 reflector and the reflector in AP600 impacted the in-  
15 vessel core melt progression significantly. Now we  
16 have a core shroud. Also the lower core support plate  
17 sits a little lower in the vessel. This is a very  
18 minor impact. I'll talk about these in a second here.

19 To implement IVR for the AP1000 there were  
20 specific things that we needed to do. We needed to be  
21 able to figure out how to increase the critical heat  
22 flux on the vessel surface because with the higher  
23 power level and the debris mass that we had, we were  
24 actually predicting not that we would exceed the  
25 critical heat fluxes that we had determined for the

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1 AP600 configuration, but we were really bumping up  
2 against them very closely.

3 We had a pitch point. We needed to figure  
4 out how to increase the critical heat flux and able to  
5 maintain the margins that we had seen in AP600.  
6 If you are going to increase the power level of the  
7 vessel, then you need to demonstrate that this thermal  
8 failure criterion is still the limiting failure over  
9 a structural failure of the reactor vessel itself.

10 If you are going to increase the heat  
11 load, you are actually going to thin the vessel a  
12 little more and you have to make sure that you still  
13 have a margin of failure structurally.

14 Because of the changes inside the vessel  
15 with the new core and the core shroud instead of the  
16 reflector, we need to investigate the in-vessel melt  
17 progression and make sure there isn't a change to the  
18 in-vessel melt progression and make sure that there  
19 isn't a change to the in-vessel melt progression that  
20 would lead to a different lower head debris  
21 configuration that we expect for AP600.

22 Also to demonstrate that the correlations  
23 that we're using for the heat transfer if they  
24 continue to scale properly for AP1000 or if we've  
25 exceeded the scaling of the testing that we had

1 already done.

2 MEMBER KRESS: Is the vessel diameter  
3 about the same?

4 MR. SCOBEL: The vessel diameter is  
5 exactly the same. The lower head geometry is the  
6 same.

7 MEMBER KRESS: Did you repeat the ROAM  
8 process for the AP1000?

9 MR. SCOBEL: Say that again, please?

10 MEMBER KRESS: Did you repeat the ROAM?

11 MR. SCOBEL: No. This is not a ROAM  
12 analysis. This is following the road map that was  
13 laid out by AP600 ROAM but it doesn't have the full --  
14 we have some tests that we've done, and I'll get into  
15 that, but we don't have like the full peer review.

16 To look at increasing the critical heat  
17 flux, we got Theo to fire up the ULPU test again. The  
18 last test that was done for AP600 was ULPU  
19 Configuration 3. This is ULPU Configuration 4. It  
20 consist of a lower-head slice geometry at a full-scale  
21 radius of reactor vessel. It gives you a full-scale  
22 simulation including all the water head and affects  
23 using a power shaping technique to simulate upstream  
24 conditions at any given test point.

25 The ULPU Configuration 4 was still set up

1 with the AP600 entrance and exit losses but we  
2 actually did not consider this to be a major  
3 limitation. We didn't think that was a limiting  
4 factor in the test.

5 MEMBER KRESS: Did you model increased  
6 decay heat with the new test?

7 MR. SCOBEL: Since we're looking for the  
8 limit, the critical heat flux limit, we were pushing  
9 the limits higher but we're not actually modeling  
10 decay heat. We are looking for the limit, not a  
11 scaled test with the decay heat. Do you know what I  
12 mean?

13 MEMBER KRESS: Yeah, I know what you mean.

14 MR. SCOBEL: The difference between -- the  
15 real difference between the two tests, between  
16 Configuration 3 and 4 is Configuration 4 had a movable  
17 baffle that conforms to the lower head. However, it  
18 was fixed at a 90 degree point. That kind of gave us  
19 a little bit of a limitation there. These tests are  
20 completed and we examine lower-head baffle geometry  
21 impacts and water level impacts.

22 MEMBER ROSEN: I assume everybody in the  
23 room knows what this acronym ULPU or UPLU is except  
24 me.

25 MR. SCOBEL: Probably not because it's not

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1 an acronym.

2 MEMBER ROSEN: Oh.

3 MR. SCOBEL: When they were first doing  
4 the tests they were being done for the Lovisa plant  
5 which also implemented an IVR program. They had a  
6 bunch of Finnish engineers that were taken from their  
7 homes in Finland and taken out to Santa Barbara.

8 MEMBER ROSEN: Cruel.

9 MR. SCOBEL: Yes, it was very cruel. One  
10 of the engineers was missing his girlfriend. Her name  
11 was ULPU and this test became his new girlfriend so  
12 the test is called ULPU. Isn't that a nice story?  
13 This is a picture of ULPU. These are the heater  
14 blocks down here. There's a riser.

15 MEMBER BONACA: She doesn't look that  
16 good.

17 MR. SCOBEL: Sorry?

18 MEMBER BONACA: She doesn't look that  
19 good.

20 MR. SCOBEL: Yeah. She's got nice wiring.  
21 There's a downcomer. I have a schematic that kind of  
22 actually shows the components a little better. This  
23 gives you an idea of the scale. There is our buddy  
24 Tony standing next to it.

25 MEMBER KRESS: When you talk about power

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1 shaping, you're talking about the distribution of  
2 energy along that surface.

3 MR. SCOBEL: Yes.

4 MEMBER KRESS: That comes from other tests  
5 that you've made or calculations of how that's  
6 distributed?

7 MR. SCOBEL: Yes. For any given test the  
8 critical heat flux is being found at a particular  
9 point. When you are doing a critical heat flux test  
10 you're not actually finding a critical heat flux shape  
11 over the whole test. You're finding -- determining  
12 the critical heat flux at 85 degrees.

13 The power in the upstream cartridges is  
14 tuned to give the proper upstream conditions in terms  
15 of void fraction and flow rate to simulate the flow  
16 over a hemispherical -- this is a constant slice  
17 geometry. It's not a pie shape. When you have flow  
18 at a given point, it's not the same flow that you  
19 would get over the slice. Do you understand what I  
20 mean? Theo has come up with an algorithm to tune the  
21 flow.

22 MEMBER KRESS: I see. It's like finding  
23 the critical heat flux off of a flat plate but  
24 changing the angle of the flat plate it looks to me  
25 like.

1 MR. SCOBEL: Yes.

2 MEMBER KRESS: It's the angle that makes  
3 the difference in the critical heat flux.

4 MR. SCOBEL: That's correct. It does.  
5 How fast you can move the bubbles away. The power  
6 shaping, I can't talk of the power shaping in  
7 significant detail how it's done but it is described  
8 in detail in the ULPU reports.

9 MEMBER RANSOM: What did you say about  
10 this? That it's just a constant width rather than a  
11 pie?

12 MR. SCOBEL: Yes. The difference is taken  
13 into account in the way the upstream heat transfer is  
14 adjusted in these -- each one of these wires is going  
15 into a cartridge that's embedded in the heater block.

16 MEMBER KRESS: Basically it looks to me  
17 like a clever way to get the effect of the angle from  
18 the critical heat flux. Where you're going you're  
19 looking at departure from nuclear boiling conditions  
20 that you get. This is just a way to do every angle.

21 You run the test so departure from nuclear  
22 boiling is apt to give a location. You don't care  
23 about really modeling the whole bottom. You're just  
24 looking for the effect of the angle and the critical  
25 heat flux.

1 MEMBER RANSOM: Well, I assume he's trying  
2 to get enough boiling as you move along the surface.

3 MEMBER KRESS: In order to get the void  
4 fraction.

5 MEMBER RANSOM: Like you said, the void  
6 fraction, bubble population would be typical of that  
7 point in the pie.

8 MR. SCOBEL: Right. Exactly.

9 MEMBER ROSEN: I'm getting a little  
10 worried about getting on with this.

11 MR. SCOBEL: Yes, sir. This is just  
12 showing the difference between the two configurations.  
13 If you look closely, the only difference is the shape  
14 of the baffle. In AP600 we have a conical baffle.

15 In this one it's more hemispherical  
16 conforming to the lower head. That comes up with  
17 increasing the critical heat flux. That's one of the  
18 effects that we get.

19 MEMBER KRESS: That has an affect on the  
20 velocity.

21 MR. SCOBEL: Yes. Exactly. What we see  
22 if we have a low water level -- here is an example  
23 with low water level -- it's just like boiling a pool.  
24 You are venting steam, you're not venting water. The  
25 flow rate is very low.

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1           Even with the baffle you can see that in  
2 ULPU Configuration 4 this line represents the results  
3 of AP600 and we're getting the same affect in AP600 as  
4 we are in Configuration 4.

5           When you fill up the -- when you have a  
6 high water level and you are venting water and steam  
7 together, you actually have very, very high flow  
8 rates. Amazingly high flow rates actually. You get  
9 a significant impact in the heat transfer. We were  
10 getting about 30 percent higher heat transfer in ULPU  
11 Configuration 4.

12           MEMBER RANSOM: Are those critical heat  
13 flux values?

14           MR. SCOBEL: These are the values of the  
15 critical heat flux, yes. There were different baffle  
16 positions but, if you remember, it was a fixed baffle  
17 at 90 degrees. When they moved the baffle it was only  
18 at the bottom.

19           MEMBER KRESS: So is that enough increase  
20 in heat flux to overcome the new higher power?

21           MR. SCOBEL: Actually, it is. Then we had  
22 some conclusions from ULPU Configuration 4. We  
23 submitted the test report to the NRC. In fact, this  
24 is the number. CHF can be increased significantly to  
25 accommodate AP1000 but we have to channel the flow

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1 around the lower head and we have to do it with a high  
2 water level.

3 AP600 didn't have this high water level  
4 restriction. We did see an adverse exit affect  
5 associated with the fact that we couldn't move the  
6 baffle up there. We still had the same AP600  
7 Configuration on top of the baffle. That leads us  
8 into ULPU Configuration 5.

9 ULPU Configuration 5 is an I-NERI funded  
10 program. It's AP1000 specific inlet and steam venting  
11 modeling including, as you were asking about the turn  
12 and the pinch point includes that. It's got a more  
13 adjustable baffle design so you can change it at the  
14 top and the bottom and everything.

15 Additional aspects that we are  
16 investigating, surface effects which you were just  
17 asking about, water chemistry and the exit phenomena  
18 that I was discussing earlier. We are using ULPU  
19 Configuration 5 to optimize the insulation.

20 These are results from ULPU Configuration  
21 5. You can kind of see that this is the line that we  
22 showed before for the AP600 correlation from the  
23 original ULPU. You can see that we're getting much  
24 higher heat fluxes. These are with the three-inch  
25 baffle at the bottom.

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1           Then also at the top we got more  
2 consistent results with the six-inch baffle at the  
3 top. In the end the final cases that we looked at  
4 were a baffle that went from three inches to six  
5 inches and we used tap water. We were getting  
6 critical heat fluxes that were much higher even than  
7 ULPU Configuration 4.

8           Part of the reason for this was with the  
9 tap water. At the end of the program they were  
10 willing to oxidize the surface of ULPU which was kept  
11 clean at the beginning. Once the surface was oxidized  
12 we got very consistent results around 2 megawatts at  
13 the top of the 90 degree point.

14           MEMBER ROSEN: And that's what you want.  
15 You want high heat fluxes.

16           MR. SCOBEL: Very high critical heat  
17 fluxes because that's our limit. That's our success  
18 criteria, success or failure.

19           MEMBER ROSEN: You're at nuclear boiling  
20 is what this says.

21           MR. SCOBEL: This is nuclear boiling.

22           MEMBER ROSEN: You get these kind of heat  
23 fluxes and it has to be nuclear.

24           MR. SCOBEL: That's correct.

25           MEMBER ROSEN: Otherwise it would drop off

1 dramatically.

2 MR. SCOBEL: Drops off amazingly fast,  
3 yes. You can see that if you look at the ULPU test  
4 report because they take it up to critical heat flux.  
5 Whenever they test a point they take it up to critical  
6 heat flux and you see the temperature excursion like  
7 it goes straight up.

8 Then they scram, allow it to cool down,  
9 and then they take it up to the last point where they  
10 achieve critical heat flux and they allow it to run to  
11 make sure that actually is like a sustainable critical  
12 heat flux point.

13 MEMBER KRESS: Now you have to show that  
14 you don't exceed these heat fluxes.

15 MR. SCOBEL: This was step one.

16 MEMBER KRESS: I'm sorry.

17 MR. SCOBEL: That's okay. So ULPU  
18 Configuration 5. These tests have shown that the  
19 AP1000 critical heat flux that we determined in ULPU  
20 Configuration 4 can be met with margin. The exit  
21 phenomena that we saw before is negligible.

22 The optimum surface that we've seen from  
23 this was unpainted and oxidized. This is being taken  
24 into account in how we are designing our installation  
25 of the reactor vessel into the plant.

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1 MEMBER ROSEN: So this is a plant where  
2 the old dictum of you could move saluted if not  
3 painted is not a very good idea.

4 MR. SCOBEL: Not with the vessel, no. We  
5 don't want -- we did test paint samples, like samples.  
6 Well, it was kind of part of the ULPU program.  
7 There's a thing called mini ULPU that they can look at  
8 -- I might be mixing up the tests. There's like a  
9 whole bunch of little tests that go along with this.  
10 They looked at a bunch of paint samples and we weren't  
11 really getting the kind of results we wanted from the  
12 painted surfaces. From the oxidized unpainted surface  
13 we get great --

14 MEMBER ROSEN: Normally oxidized just  
15 because the plant runs.

16 MR. SCOBEL: Yes.

17 MEMBER ROSEN: Do you have to preoxidize?

18 MR. SCOBEL: It will oxidize on its own.  
19 It gets a late oxidation. With us and CE now being  
20 partners we have like a lot of experience and we had  
21 some really interesting discussions with CE because  
22 they don't paint their reactor vessels. They said you  
23 get a light oxidation and then it stays that way.

24 MEMBER ROSEN: Just build a vessel and put  
25 it out there in Chattanooga in the backyard for

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1 awhile.

2 MR. SCOBEL: They use a strippable coating  
3 that they take off once they install it. It protects  
4 it when it's sitting out in the yard. Then when they  
5 take it off they come and they say it's handstripped  
6 away from the vessel.

7 MEMBER KRESS: I'm envisioning hot debris  
8 inside the vessel melting away some of the metal to  
9 the inside. It's thin enough that you can carry the  
10 flux out through it but it's accepted by the less than  
11 the critical heat flux on the outside. You thin it  
12 around. You've got a heavy start in there and maybe  
13 you thin it so much that at that temperature it can't  
14 stand the weight. That's what you call structural  
15 failure.

16 MR. SCOBEL: Yes.

17 MEMBER KRESS: What do you call thermal  
18 failure?

19 MR. SCOBEL: Thermal failure is exceeding  
20 the critical heat flux.

21 MEMBER KRESS: It's going to melt through  
22 that spot?

23 MR. SCOBEL: Yes. I would envision that  
24 it would melt through the whole way around because it  
25 would get so hot.

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1 MEMBER KRESS: Which is also a structural  
2 failure that happens a lot differently. It happens  
3 because --

4 MR. SCOBEL: Because it melts through.

5 MEMBER KRESS: It melts through. Okay.

6 MEMBER ROSEN: It melts through because it  
7 exceeded the critical heat flux.

8 MR. SCOBEL: Exactly.

9 MEMBER KRESS: The other way is just  
10 weight. Just basic creep rupture.

11 MR. SCOBEL: Yes.

12 MEMBER KRESS: Because the metal is thin.

13 MR. SCOBEL: Yes.

14 MEMBER RANSOM: I have a question. Has  
15 the Thermal Hydraulic Subcommittee ever reviewed this  
16 experiment?

17 MEMBER KRESS: We have reviewed it to some  
18 extent for AP600. We had Theofanous come in and talk  
19 about the attendance in the ROAM. This was some time  
20 ago. We haven't reviewed these new experiments. At  
21 some point you're going to talk about the heat  
22 transfer on the inside?

23 MR. SCOBEL: Yes. For the structural  
24 failure we wanted to confirm at the higher power level  
25 that we were still okay and considering abounding heat

1 flux of 2000 -- the heat fluxes that we are expecting  
2 from AP1000 are actually about 1,400 or 1,500  
3 kilowatts per square meter so this is a heat flux.

4 The vessel is still carrying 36 times the  
5 thickness that it needs to carry at that load which is  
6 on the same order of magnitude as AP600. AP600 was  
7 more like 70. It was like double that.

8 MEMBER KRESS: Is the heat flux still  
9 maximum in the metal layer?

10 MR. SCOBEL: Yes. This is a maximum.  
11 Actually when you consider that this is about the  
12 critical heat flux, it's about the biggest heat flux  
13 that you can stand. Even at a lower heat flux this  
14 would be more like 50 or 60.

15 Here we get to in-vessel melt progression  
16 which is leading up to what we're taking about. The  
17 AP600 in-vessel melt progression was strongly  
18 influenced by having a low power density and --

19 MEMBER KRESS: MAAP 4 results?

20 MR. SCOBEL: No. This is talking about  
21 what we did for AP600 and then how it relates to  
22 AP1000.

23 MEMBER KRESS: How did you get to AP600  
24 in-vessel melt progression, MAAP 4?

25 MR. SCOBEL: No. Actually, it was done

1 with a bunch of engineers working on it for a long  
2 time because you can't model the details with MAAP 4,  
3 the details of how things progress with MAAP 4 so  
4 there were models that were done that you could  
5 consider to be almost like hand calculations.

6 First principle calculations if you will.  
7 The melt progression -- and it was like not one person  
8 but it was like Theo and people from Argonne, Senece  
9 and Company and Ruth Spencer's group.

10 MEMBER KRESS: This was part of the ROAM  
11 process?

12 MR. SCOBEL: This was part of the ROAM  
13 process. It was not like one day. It was like a one-  
14 year program to come up with the melt progression for  
15 AP600.

16 MEMBER KRESS: It boils down to expert  
17 opinion on the probability of these things happening?

18 MR. SCOBEL: There was expert opinion  
19 involved, yes. But the conclusions that were  
20 important was that the downward relocation halfway is  
21 blocked which is consistent with things like Three-  
22 Mile Island.

23 You have a sideward failure through the  
24 reflector into the dead-ended region which would then  
25 allow the debris to contact the core barrel. The core

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1 barrel would fail and the debris would relocate into  
2 the lower head.

3 Some other things that aren't specifically  
4 up there. In AP600 the reflector around the core was  
5 a very thick chunky piece of metal. It was five  
6 inches thick.

7 MEMBER KRESS: Does that protect the  
8 vessel against radiation embrittling or was it a  
9 thermal barrier or neutron effect?

10 MR. SCOBEL: It was for neutronics and it  
11 also protected the vessel from fluents. I'm speaking  
12 a little beyond my complete knowledge. There was this  
13 big chunky reflector there. It was a strong thermal  
14 barrier.

15 The core melt progression downward was a  
16 lot faster than melting through the reflector so  
17 consequently in AP600 you essentially have to melt the  
18 entire core before it can generate enough energy to  
19 melt through the reflector and then through the core  
20 barrel.

21 When you got the initial relocation into  
22 the lower head, you would have this oxide pull that  
23 would melt through the reflector and then the core  
24 barrel and then pour down into the lower head and  
25 contact the lower support plate from below. It all

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1 occurred in kind of one fell swoop and filled up and  
2 contacted the lower support plate.

3 AP1000 has a higher core power density and  
4 a core shroud instead of a reflector so we really need  
5 to investigate how we expect the AP1000 core melt  
6 progression to progress.

7 This is a picture of the core shroud which  
8 is not really compared to the reflector but the shroud  
9 part itself is seven-eighths of an inch thick around  
10 the core and it has the support rings on the outside.

11 At the bottom there's a four-inch thick  
12 plate and it has 16 cooling holes that go through it.  
13 Each of these holes is about three-quarters of an inch  
14 in diameter. They go down and they turn 90 degrees  
15 and they get their cooling flow from below the top of  
16 the -- the bottom of the active fuel.

17 This is under normal circumstances you  
18 have a bypass flow that goes through the core shroud  
19 there. Then the core barrel sits on the outside and  
20 these rings kind of rest inside the core barrel. This  
21 is the lower support plate.

22 MEMBER KRESS: All that is steel?

23 MR. SCOBEL: It's all stainless steel. So  
24 in modeling this core relocation, the first thing we  
25 needed was an accident sequence, by definition a

1 successful IVR fully depressurized. We want to look  
2 at the earliest core uncover core melt progression  
3 because of decay heat being higher so that's  
4 conservative.

5 We don't want the vessel to be reflooded  
6 inside because our bounding case is no water in the  
7 vessel cooling. We were only cooling the core from  
8 the outside. What I conservatively assumed, it  
9 doesn't have anything to do with probability or  
10 anything, I just looked at a spurious ADS stage 4 case  
11 because you can't reflood the vessel. It's a large  
12 LOCA. It's very early. It progresses very rapidly.  
13 This was my case.

14 I did run MAAP 4 cases but because I'm  
15 looking at detailed heat up of the core internals, the  
16 MAAP 4 model for the core internals are very prude.  
17 If you're looking at the core melting they are fine  
18 for that. If you are looking at how the core shroud  
19 and core barrel heat up, they are not so good for  
20 that. We put together a Finite difference model of  
21 the core and internals which used the uncover timing  
22 from MAAP 4.

23 Now, this model had its limitations in  
24 that it actually couldn't model the melting and  
25 relocation of the core once it heated up to a certain

1 level. We also have --

2 MEMBER KRESS: Finite difference models  
3 are usually fixed geometry.

4 MR. SCOBEL: Fixed geometry. Exactly. To  
5 supplement what we did with MAAP 4 and what we did  
6 with that, we also have hand calculations of the core  
7 heat up and melting that were much like what was done  
8 for AP600 to look at how it would relocate to the  
9 different regions of the reactor vessel and then heat  
10 up.

11 The first thing we see is the formation of  
12 a in-core debris pool. During the melting process  
13 -- the heat up and melting process we actually see  
14 that the upper parts of the core shroud melt actually  
15 prior to the fuel melting.

16 MEMBER KRESS: Radiation?

17 MR. SCOBEL: It's from radiation. Heat  
18 transfer from the fuel. When it's getting up close to  
19 its melting temperature, the inside of the shroud  
20 would melt and we saw and thinning of the core barrel  
21 as well. It's very overheated.

22 Most of the peripheral fuel assemblies,  
23 though, by radiation cooling to the core barrel and to  
24 the core shroud remain intact so you have this  
25 boundary around the core of intact fuel assemblies.

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1 We expect a blockage -- an oxide blockage to occur at  
2 one meter above the bottom of the fuel.

3 This is significant because if you  
4 remember what I said in AP600 we melted the entire  
5 core before we were able to melt out through the sides  
6 of the reflector and the core barrel. Now, in AP1000  
7 we don't melt the entire core. We have a blockage.

8 At the point where you get an oxide debris  
9 pool that can then generate super heat and fail  
10 through the side, you already have the core -- not the  
11 reflector but the shroud is already melted so the  
12 boundary is actually inside the oxide fuel assemblies,  
13 the peripheral fuel assemblies that are intact.

14 When they fail the in-core debris pool  
15 will then pour down into between the bottom shroud,  
16 which is still there, and the core barrel. It will  
17 fill up contacting the core barrel which is  
18 significantly overheated and you have a sideward  
19 failure at the top of the oxide pool that then allows  
20 the debris to core down into the lower head.

21 MEMBER ROSEN: Top of the oxide?

22 MR. SCOBEL: That's actually where the  
23 heat flux -- because when you have the in-core debris  
24 pool you have strong heat fluxes upward.

25 MEMBER SIEBER: I would have sort of

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1 guessed that the oxidation of the cladding would have  
2 been so severe prior to this happening that the fuel  
3 would more or less fall apart before it melted.

4 MR. SCOBEL: In the peripheral fuel  
5 assemblies?

6 MEMBER SIEBER: Yes. Is that potentially  
7 the case or not? Because there's going to be a lot of  
8 oxidation going on.

9 MR. SCOBEL: Yes, there is a lot of  
10 oxidation. You do have less in the peripheral fuel  
11 assemblies, actually.

12 MEMBER SIEBER: That's true.

13 MR. SCOBEL: But the temperatures that  
14 we're seeing led us to predict that they were still  
15 standing.

16 MEMBER SIEBER: Still standing.

17 MR. SCOBEL: You see, this is --

18 MEMBER SIEBER: It probably doesn't make  
19 a difference.

20 MR. SCOBEL: It's also a conservative  
21 assumption. I'm sorry. It's a conservative  
22 assumption, too. There's like so much stuff to this  
23 that keeping track of it is difficult. But it's  
24 conservative also to assume that the peripheral fuel  
25 assemblies are standing because it significantly

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1 limits the mass associated with this initial  
2 relocation which, as we continue to talk about the  
3 progression, it sounds funny that we want more melted  
4 fuel but we do. What we want to do is we want to  
5 contact the lower support plate like we did in AP600  
6 to melt the metal debris on top of the oxide debris.

7 MEMBER ROSEN: You need to pick up the  
8 pace a little bit.

9 MR. SCOBEL: I'm sorry. There's so much to  
10 this.

11 MEMBER ROSEN: I know, but we only have --

12 MEMBER KRESS: Let me make one comment  
13 here. The committee normally deals in the  
14 propabalistic world and view this as one potential  
15 melt progression description out of a number of  
16 possible ones.

17 Normally they would think in terms of the  
18 worst configuration you could have and what is the  
19 probability I'm getting that configuration and does  
20 that worst configuration fail through the vessel by  
21 any means. It's a little difficult to accept one  
22 description of core melt degration. There are  
23 probably other possible ones. That's my initial  
24 reaction right now.

25 MR. SCOBEL: The other really likely

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1 scenario that I could potentially think of would be --  
2 it's not very likely because --

3 MEMBER KRESS: I would make a scenario  
4 independent. I would ask myself given this stuff in  
5 the core that I have, what is the worst condition down  
6 there that I can have that would cause it to melt  
7 through. Is there some configuration in there that  
8 would cause it to fail? Then back into that and say  
9 what is the probability of me getting that.

10 MR. SCOBEL: Actually --

11 MEMBER KRESS: You don't have to get into  
12 scenarios.

13 MR. SCOBEL: This is the process that I  
14 went through. In doing this I was partnered with  
15 FORDUM, Aali Kimeleinen. Actually, the guy you named  
16 the ULPU test. We actually were trying to fail the  
17 vessel in doing this. This is the core melt  
18 progression that we came up with knowing what we know  
19 about how it's going to melt.

20 The downward relocation you have a whole  
21 lot of frozen metal down here and it's just solid at  
22 the top of the core support plate. It's not going  
23 anywhere. Because of the melting of the core shroud  
24 and core barrel, those tiny little holes at the bottom  
25 of a core shroud are blocked.

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1 Not only that, the exits to them are  
2 blocked with metal as well. The only failure scenario  
3 for getting the debris out through from up here to  
4 down here is through the side. There's really no  
5 other place for it to go. The way that it would come  
6 through the side because we were saying the core  
7 barrel up here is heated up and overheated but the way  
8 that it comes through the side is by melting the core  
9 barrel.

10 The way that it melts the core barrel is  
11 you have a debris pool with super heat in it and so  
12 it's going to start the melt and where the highest  
13 heat flux is with the debris pool. That occurs at the  
14 top of a pool because of the natural circulation in  
15 the pool. You fail the debris pool and then you kind  
16 of oblate a hole as the debris pours through the hole.

17 MEMBER KRESS: Then what I would have done  
18 is take that debris and set it on the bottom of the  
19 vessel.

20 MR. SCOBEL: Yes.

21 MEMBER KRESS: I'm not quite sure how deep  
22 it is. I would look at different depths and see if  
23 there is some optimum depth to fail the vessel.

24 MR. SCOBEL: We looked at how deep the  
25 debris would be next.

1 MEMBER KRESS: I don't know how deep it  
2 is.

3 MR. SCOBEL: Well, we know what a minimum  
4 mass would be because minimum would be bad.

5 MEMBER KRESS: That's why I said lower  
6 mass because you're concentrating it down with a bad  
7 heat intake.

8 MR. SCOBEL: In terms of minimum mass it's  
9 like we held up the peripheral fuel assemblies, we  
10 held up what ends up between where the core shroud and  
11 core barrel would be. We held up as much debris as  
12 possible. We had a minimum debris relocation of 6.2  
13 cubic meters.

14 MEMBER KRESS: That's getting close to  
15 what I was saying.

16 MR. SCOBEL: I think we're on the same  
17 page. It's just that I'm trying to go through this  
18 quickly.

19 MEMBER ROSEN: And the 14-foot fuel,  
20 that's two feet of it left?

21 MR. SCOBEL: That's actually about a  
22 meter.

23 MEMBER KRESS: So you've got --

24 MR. SCOBEL: That's conservatively high.

25 MEMBER KRESS: You've got competition

1 between label that and the heat transfer and the  
2 thinning of that vessel down there.

3 MR. SCOBEL: Yes. Well, down here you  
4 have water.

5 MEMBER KRESS: Oh, there's water down  
6 there?

7 MR. SCOBEL: Yeah, there's water that's up  
8 to about the bottom of active fuel.

9 MEMBER KRESS: You're going to boil that  
10 off?

11 MR. SCOBEL: Yes. Now, what you have is  
12 a horse race between how fast this debris up here  
13 melts and pours into the lower head versus how long  
14 the water will last. That's the next slide. Actually  
15 what we see -- and we make conservative assumptions on  
16 how long the water is going to last.

17 We assume actually that based on boiling  
18 the water, we assume that we filled up the entire  
19 lower head which we haven't done so we put more heat  
20 into the water than is actually there. We have done  
21 this on a conservative basis trying to fail it and  
22 having math errors and thinking that we failed it and  
23 then finding them.

24 In the end what we came up with, since I  
25 have to go fast, we have like an early timing and a

1 duration for relocation. This is for our modeling of  
2 the subsequent relocation of the debris. We model  
3 each of the regions and we keep track of how much heat  
4 is in each one and how much mass based on our  
5 conservative calculations of how much initially  
6 relocated.

7 What we come out with for success we say  
8 the debris contacts the lower support plate before you  
9 get to dry out. This is for mitigating the focusing  
10 effect. We get a debris contact occurring at -- well,  
11 times zero is 6,000 seconds so it's like 717 seconds  
12 after the initial relocation. The lower plenum dryout  
13 occurs.

14 Like I said, this was conservatively  
15 calculated quickly at 6,888 seconds. What this means  
16 is that we expect all the transient debris  
17 configurations that would be in the lower head before  
18 you contact the support plate to be water-cooled.  
19 Once you contact the lower support plate, then the  
20 focusing effect is mitigated by the amount of debris  
21 that you can melt into the lower head.

22 MEMBER KRESS: Did you take any credit for  
23 this in assessing or design basis accidents in the  
24 SAR?

25 MR. SCOBEL: Design basis accidents don't

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1 have melting fuel.

2 MEMBER KRESS: This is all for the PRA?

3 MR. SCOBEL: This is all for the PRA.

4 This is all for IBR specifically.

5 MEMBER RANSOM: Do you have a severe  
6 accident model that you use to do the thermal  
7 calculations and relocation? Does MAAP give you that?

8 MR. SCOBEL: We actually did it with --  
9 this is a schematic of the model we used and it was  
10 done on a spreadsheet.

11 MEMBER KRESS: This is all to support your  
12 success assumption in the PRA?

13 MR. SCOBEL: Yes.

14 MEMBER KRESS: You've got depressurized  
15 and water in the cavity, then you don't fail.

16 MR. SCOBEL: Yes. This is basically to  
17 come up with the debris configuration in the lower  
18 head to justify metal over oxide debris configuration.  
19 We are relocating oxide and it's contacting the lower  
20 head. It's contacting the lower support plate from  
21 the bottom and melting.

22 MEMBER KRESS: What's happening to that  
23 melting debris while you're having the race going on?

24 MR. SCOBEL: Down here?

25 MEMBER KRESS: Yes. It's got a crust?

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1 MR. SCOBEL: It's got a crust. It's got  
2 water. It's cooled with water.

3 MEMBER KRESS: So you're not melting the  
4 head during that part?

5 MR. SCOBEL: No. It means that the heat  
6 fluxes from the debris in the lower head to the lower  
7 head are bounded by the final steady state debris that  
8 you get when you have a full natural circulating  
9 debris pool.

10 MEMBER KRESS: Yeah, but do you think an  
11 oxide crust on the bottom of that pool provides any  
12 protection to the lower head?

13 MR. SCOBEL: Yes.

14 MEMBER KRESS: Do you have a model that  
15 says that?

16 MR. SCOBEL: Just based on the heat  
17 transfer calculations that we do for assessing the  
18 final steady state IVR configuration.

19 MEMBER KRESS: Steady state is okay in  
20 this case and I don't mind that. I would like to see  
21 the model because only a crust will adjust its  
22 thickness to accommodate the heat flux through it.

23 MR. SCOBEL: That's taken --

24 MEMBER KRESS: It's the heat flux and the  
25 temperature that you get on the bottom side that

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1 determines whether you're melting it.

2 MR. SCOBEL: That's actually taken into  
3 account, yes. That's all taken into account.

4 MEMBER KRESS: Show me where the  
5 documentation is.

6 MR. SCOBEL: It's all based on the same  
7 model from the AP600 ROAM. The crust has an inside  
8 surface temperature that is the liquid of the oxide.

9 MEMBER KRESS: Of the oxide. Right.

10 MR. SCOBEL: Yes. And so you have an  
11 isothermal boundary around.

12 MEMBER KRESS: You have an isothermal  
13 boundary so the crust adjust its thickness.

14 MR. SCOBEL: Yes. So you --

15 MEMBER KRESS: You get the heat flux.

16 MR. SCOBEL: And you get the heat fluxes  
17 from the natural circulation so when you get each of  
18 those heat fluxes you calculate a crust thickness  
19 based on the heat flux.

20 MEMBER KRESS: And that fixes the metal  
21 temperature.

22 MR. SCOBEL: And that fixes -- exactly.

23 MEMBER KRESS: And that's the model you  
24 have?

25 MR. SCOBEL: Yes, sir. That's exactly!the

1 model we have.

2 MEMBER KRESS: Ok'y.

3 MR. SCOBEL: RASPLAV and MASCA. We had  
4 specific questions about RASPLAV and MASCA. We  
5 address these in detail in REI720047. These are in-  
6 vessel material testing using prototypic materials.  
7 However, the conditions for RASPLAV and MASCA are not  
8 prototypical. The really numbers are too low.

9 MEMBER KRESS: You don't have enough for  
10 the --

11 MR. SCOBEL: Yeah, you can't get the  
12 scale. You can't get it big enough.

13 MEMBER KRESS: You can't get it big  
14 enough.

15 MR. SCOBEL: Right. Really numbers are  
16 too low. Heat fluxes are too high and they are coming  
17 from the wrong places like they use radiant heating in  
18 some cases which is from outside the debris, not  
19 inside the debris so the crust are all wrong. They  
20 don't have acceptable ratios of the masses.  
21 Consequently I don't really think we draw a whole lot  
22 from them.

23 MEMBER KRESS: It's not prototypic enough  
24 for AP1000.

25 MR. SCOBEL: No. But we don't believe

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1 that they contradict our position because for our  
2 conditions --

3 MEMBER KRESS: What did they find out in  
4 RASPLAV and MASCA?

5 MR. SCOBEL: There were certain cases  
6 where they had reactions between metals and oxide that  
7 resulted in --

8 MEMBER KRESS: Material interactions.

9 MR. SCOBEL: Yeah, material interactions  
10 between where they had a bottom uranium layer, uranium  
11 and steel.

12 MEMBER KRESS: If you've got uranium and  
13 steel in the bottom, you fail the vessel.

14 MR. SCOBEL: Not necessarily. No,  
15 actually.

16 MEMBER KRESS: It depends on whether they  
17 carry any heat flux.

18 MR. SCOBEL: Well, it depends on that. It  
19 depends on how much heat flux it carries. It depend  
20 on how much metal it takes away because if you assume  
21 that you react like a whole lot of it and you can  
22 assume that it thins the top metal layer. Those  
23 interactions are --

24 MEMBER KRESS: Are they exothermic?

25 MR. SCOBEL: They are actually oxidation

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1 reduction reactions so they aren't strongly exothermic  
2 at all.

3 MEMBER KRESS: Almost neutral.

4 MR. SCOBEL: Yeah.

5 MEMBER RANSOM: Who made these tests?  
6 Where were they done?

7 MR. SCOBEL: They were done in Russia and  
8 they were sponsored by CSNI and OECD? I'm asking Bob  
9 Palla.

10 MR. PALLA: I think yes.

11 MR. SCOBEL: Bob Palla thinks yes.

12 MEMBER RANSOM: And the data is open?

13 MR. SCOBEL: I don't believe it is.

14 MEMBER RANSOM: How are you able to use it  
15 then?

16 MR. SCOBEL: I'm not actually using it.  
17 I'm asking people for assessments, people who have the  
18 data. I rely on people who are able to see the data  
19 and I have not seen it. That's why I'm kind of like  
20 this is what I know about it. There are open papers  
21 of results but the overall program is not open.

22 MR. SNODDERLY: Dr. Ransom, this is Mike  
23 Snodderly. I think later on we're going to hear from  
24 the staff and Richard Lee from the Office of Research.  
25 The Office of Research is one of the sponsors of the

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1 RASPLAV experiments and hopefully they will be able to  
2 give us some more information and the availability of  
3 the data.

4 MEMBER RANSOM: Good.

5 MR. SCOBEL: Okay. So let me get into the  
6 application of heat transfer coefficients. The bottom  
7 line is that we are not really violating still even  
8 with our higher power levels. We're getting toward  
9 the top of the oxide debris pool heat transfer but we  
10 are still within the range of the data.

11 We are well within the metal layer heat  
12 transfer data. We have a modest extrapolation for the  
13 Globe-Dropkin correlation. However, it's only for  
14 really thick metal layers and thick metal layers  
15 aren't the ones that give us problems. It's when you  
16 thin the metal later.

17 MEMBER RANSOM: The question I have, you  
18 talked about these metal layers. Are there test data  
19 or calculations that indicate that you actually would  
20 have something like that in a severe accident?

21 MR. SCOBEL: Actually have a metal layer?

22 MEMBER RANSOM: Right. Do you get the  
23 separation of the layers?

24 MR. SCOBEL: You do. Even in RASPLAV and  
25 MASCA they saw the separation of the layers. Those

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1 would be the tests where we would --

2 MR. BEHBAHANI: This is Ali Behbahani from  
3 Office of Research. As Mike as noted, Office of  
4 Research is participating in MASCA and RASPLAV. In  
5 RASPLAV experiment they did test four different type  
6 of corium compositions, 100 percent oxidic and then  
7 they lowered the oxidation rate of the corium.

8 In the RASPLAV experiment it was shown if  
9 you add carbon to the mass you have a certification of  
10 the melt where you have two layers of oxidic melt.  
11 One richer in metal than the lower one.

12 In MASCA experiment it was mainly done  
13 from material point of view where you had zirconium  
14 containing corium. Then we added iron to it and then  
15 you get separation. Thereby you have heavy metal  
16 relocated to the lower part of the mass next to the  
17 vessel wall.

18 If I recall correctly, the density of the  
19 metal melting relocated to the lower part of plenum  
20 was about 12 percent higher than the oxidic melt  
21 itself. It was very heavy. I don't know whether you  
22 can mix the whole thing even if you have such a high  
23 number with that variation of densities. This is the  
24 finding so far in MASCA experiment.

25 In addition, I should mention addition of

1 boron carbide to the melt in addition to iron that  
2 accentuates this whole melt separation where you have  
3 larger amount of metallic melt relocated to the  
4 bottom.

5 MEMBER RANSOM: I guess the important  
6 thing would be that your model is considered to be  
7 conservative and you are sort of taking a worst case  
8 type situation where you get the highest heat transfer  
9 and assume natural circulation exist in these layers.  
10 Is that what you're doing?

11 MR. SCOBEL: Yes. It actually is. You  
12 can say can you have a worst case with like a heavy  
13 metal layer on the bottom. Depending on assumptions  
14 of how you partition the heat, heat doesn't go with  
15 uranium. It's in the fission products, not the  
16 uranium. If you sink uranium metal layer to the  
17 bottom and it has no -- it doesn't have like all of  
18 the decay heat in it, then --

19 MEMBER KRESS: Then it just helps you.

20 MR. SCOBEL: Yeah. It's not a problem.

21 MEMBER KRESS: Tests have shown that when  
22 you do that the metals strip out the metallic fission  
23 products to some extent. It does carry fission  
24 products with it. You would expect them to go with  
25 it.

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1 MR. SCOBEL: But it actually has to carry  
2 a lot of fission products with it. It's not just --  
3 if it's like 20 percent, it's still okay.

4 MEMBER KRESS: It does boil down to how  
5 much internal heat generation metal will carry with  
6 it.

7 MR. SCOBEL: But if you have these natural  
8 circulation rates that we are considering, you know,  
9 peak the heat fluxes at particular points on the  
10 vessel, and we're looking at peak heat fluxes  
11 conservatively at the top of the oxide layer, in the  
12 metal layer, depending on how much metal you can  
13 include in the debris which comes down to whether or  
14 not you can contact the support plate. We are trying  
15 to look at it, you know, conservatively but not overly  
16 conservatively. It's a PRA so we're trying --

17 MEMBER KRESS: Overly conservative would  
18 be put the metal on the bottom and put all the heat  
19 in.

20 MR. SCOBEL: Yeah.

21 MEMBER KRESS: That would be going too  
22 far.

23 MR. SCOBEL: Yes.

24 MEMBER RANSOM: Well, I know people like  
25 SCDAP. There's another severe accident code around

1 they use.

2 MR. SCOBEL: MELCOR.

3 MEMBER RANSOM: MELCOR.

4 MR. SCOBEL: It's a lot like MAAP.

5 MEMBER RANSOM: I know they are doing a  
6 lot of work with the Europeans on this sort of thing  
7 and I'm wondering is that available to you to try to -  
8 - at least it has some mechanism in an attempt to  
9 model where the sources of energy are and whether  
10 separation is occurring, melting of the materials.

11 MR. SCOBEL: I'm not aware of their  
12 studies. I don't know who's doing that.

13 MEMBER RANSOM: But you're not using any  
14 severe accident codes to drive what you're doing here,  
15 I guess?

16 MR. SCOBEL: No, not right here. This is  
17 done in calculations specifically --

18 MEMBER RANSOM: I would think it would be  
19 of some concern to the NRC how your calculations,  
20 whether they would agree or disagree with what is  
21 predicted from some of the severe accident codes.

22 MEMBER KRESS: Most of those severe  
23 accident codes when they --

24 MEMBER ROSEN: Could you talk into the  
25 microphone?

1                   MEMBER KRESS:    Most of those severe  
2 accident codes when the debris goes to the lower head,  
3 a few tens of seconds later it goes through the head  
4 because the outside of the head is not cooled.  You  
5 would have to modify those codes to take care of this  
6 cooling on the outside.  Plus, they don't have real  
7 detailed models for the natural circulation in a pool.

8                   MEMBER RANSOM:  Well, I know they attempt  
9 to do that.

10                  MEMBER KRESS:  It's not very important in  
11 those codes because every time you get the debris down  
12 there it goes right through the head so they don't  
13 need to pay much attention to it.  Here you've got a  
14 different situation and you need to do a little better  
15 job, I think, of modeling the heat transfer in a pool.  
16 You might learn some things about this melt  
17 progression and what gets down there in the first  
18 place by using some of those codes.

19                  MEMBER RANSOM:  That's what I would be  
20 concerned with is are these really conservative.

21                  MEMBER KRESS:  Does he have the right  
22 materials down there at the right timing and places.  
23 You might learn some things and get some insight on  
24 that.

25                  MR. SCOBEL:  I don't know if this answers

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1 your question but if I were to model this in the MAAP  
2 code with AP1000 I don't fail the vessel. MAAP has  
3 lower head cooling models.

4 MEMBER KRESS: Oh, MAAP does.

5 MR. SCOBEL: MAAP does. I don't fail the  
6 vessel and it's not that I don't trust the MAAP result  
7 but I want to look at it in more detail. MAAP doesn't  
8 model the specific in-vessel core relocation effects  
9 that we have modeled outside of the code.

10 It doesn't -- it uses like five rings on  
11 the lower head to model the vessel and we're trying to  
12 look at this more detailed with the natural  
13 circulation from the testing that we have and to  
14 figure out if we believe that the lower head will stay  
15 intact for IVR and if we have margin. That's kind of  
16 the next slide.

17 MEMBER ROSEN: Let me just point out we've  
18 got 45 minutes left until we can adjourn for the  
19 morning. Between you and Selim we've got a couple of  
20 important conclusary topics to make. However you  
21 figure it out but by 12:15 we are going to adjourn.

22 MR. SCOBEL: Okay. I think I'm almost  
23 done with this. Talking about heat transfer and say  
24 we scale okay. Quantification of the thermal loads.  
25 Now that we have a model for the lower head we have a

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1 metal over oxide debris pool configuration.

2 We use the DOE methodology that Theo developed. We  
3 are using the new critical heat flux from ULPU  
4 Configuration 4.

5 We use AP1000 specific input parameters on  
6 geometry and heatloads. We developed some probability  
7 distributions for uncertain parameters such as the  
8 fraction of cladding reaction, the mass of stainless  
9 steel that would be included in the debris, and the  
10 timing with respect to shutdown.

11 This is a bounding calculation just to  
12 show you the critical heat flux line with the 30  
13 percent increase from ULPU Configuration 4. This line  
14 here is the heat flux, the solid line. This dotted  
15 line in between is the ratio of the heat load to the  
16 critical heat flux for this calculation.

17 In AP600 where we were down around here  
18 and AP1000 was up around 70 percent for a bounding  
19 calculation. We have a probability distribution for  
20 the three places that we look at that are specifically  
21 where you would expect failure to occur, at the bottom  
22 of the lower head, at the top of the oxide pool, or  
23 the bottom of the metal pool.

24 The probability distributions of the heat  
25 loads look like this out here at the maximum. You can

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1 see we are about the same place for that bounding  
2 calculation that I presented earlier which is about 70  
3 percent.

4 Our conclusions were that we have  
5 demonstrated that IVR is successful for the AP1000.  
6 we have a margin of failure that's similar to AP600,  
7 not quite as much. We had to increase the critical  
8 heat flux which leads us to other success criteria  
9 with respect to operator actions flooding the cavity.

10 We have a new structural requirement on  
11 our insulation that AP600 was required. Basically the  
12 structure of the insulation couldn't break free to  
13 block flow paths. We now have a structural limitation  
14 from the lower head that it actually forms the baffle  
15 around the lower head to increase the critical heat  
16 flux with the velocity of the flow. We need to have  
17 deep flooding of the reactor cavity.

18 That's the end of the IVR presentation.

19 MEMBER ROSEN: Now, we explored a little  
20 bit model uncertainty. To me the most salient point  
21 is does this thing progress the way you say it does?

22 MR. SCOBEL: Yes.

23 MEMBER ROSEN: Tom asked a few questions  
24 about that. I guess what I'm struggling with is  
25 trying to get the confidence that the sequence is as

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1 you suggest. Did you do any similar calculations for  
2 other model or sequences of the melt progression and  
3 assure yourselves that this is the most severe one?

4 MR. SCOBEL: Yes. I have some bounding  
5 calculations that I've done for looking at heat loads  
6 from metal on the bottom. Having metal on the bottom  
7 and sending the upper metal layer.

8 Obviously if you put heat load into the  
9 bottom, then you don't have the same -- then this  
10 comes down to do you put all the decay heat in the  
11 bottom metal layer? How much of the decay heat do you  
12 put in? I have some backup slides actually if you  
13 want to see them. I haven't presented these anywhere  
14 before.

15 MEMBER ROSEN: It's up to you -- the  
16 question is on the table -- how you want to address  
17 it.

18 MR. SCOBEL: Okay. To assess heat  
19 transfer in the bottom metal layer, if you look at ---  
20 start out by looking at this INEL report that has a  
21 model for key transfer of the bottom metal layer and  
22 it's not right.

23 I don't know if there's a map there or  
24 something but they have some conditions that are  
25 actually similar to what I would say would be a

1 bounding condition for AP1000. The heat flux that  
2 they are getting at the bottom of the vessel is  
3 uniform over the entire bottom metal layer. It's like  
4 4 megawatts.

5 If you look at the -- it's really high, 4  
6 megawatts per square meter. If you look at it, that  
7 assumes that over that area that's all of the decay  
8 heat. It's like 100 percent of the decay heat.  
9 That's not right.

10 I started looking at that and I was like  
11 I did a calculation and to get heat fluxes through a  
12 metal layer like that it's like tens of thousands of  
13 degrees to conduct that kind of energy. Even if you  
14 assume less energy through half a meter or whatever  
15 you expect this bottom metal layer to be thick.

16 You get like tens of thousand degrees to  
17 transfer any kind of a heat flux through the bottom.  
18 Heat just doesn't really want to go down like that.  
19 What that means is you're going to end up with like a  
20 stratified bottom metal layer.

21 You're going to have the bottom part  
22 conducting to the vessel wall and the top part is  
23 going to have a natural circulation flow in it that's  
24 going to be conducting upward into the oxide layer.

25 You have a total thickness of the metal

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1 layer and you have some thickness of it that is the  
2 conducting part and you're going to have some  
3 thickness of it that is the convecting part. the  
4 boundary between those two layers is going to be a  
5 common temperature. You can kind of draw this up  
6 as --

7 MEMBER KRESS: Is that a solid restrictor  
8 or is that just temperature because that's an in-layer  
9 down there that doesn't circle it.

10 MR. SCOBEL: You mean this temperature?

11 MEMBER KRESS: Is the bottom layer a  
12 solid?

13 MR. SCOBEL: No, it's just not  
14 circulating.

15 MEMBER KRESS: Just not circulating.

16 MR. SCOBEL: Yes.

17 MEMBER KRESS: Okay.

18 MR. SCOBEL: Just not circulating. And  
19 then this is the vessel wall. This is your boiling  
20 temperature so it's like saturation. Then you can  
21 kind of pull these things all together with some  
22 assumptions. First of all, I'm using this because I'm  
23 not real smart and I can't do curved geometries and  
24 stuff like that. I used an infinite slab.

25 PARTICIPANT: Two dimensional.

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1 MR. SCOBEL: It's just -- yes. It's  
2 actually one dimensional. This is conservative at the  
3 minimum margin point of zero degrees because that  
4 would be where it's thickest if you're looking at it  
5 in one dimension. This is kind of like a bounding  
6 calculation which you like.

7 Now, another assumption I'm making is the  
8 bottom metal layer has 40 percent weight percent of  
9 uranium which is consistent with the assumptions that  
10 were in the INEL document and also the peer review  
11 comments that Theo got from Professor Olander.

12 Now, I'm assuming that 100 percent of the  
13 decay heat from the fission products that come from an  
14 equivalent volume of the oxide needed to create that  
15 amount of uranium went along with the uranium so this  
16 is conservative.

17 MEMBER KRESS: Just a DTSE ratio there.

18 MR. SCOBEL: Sorry?

19 MEMBER KRESS: Take the total inventory  
20 and DTSE ratio.

21 MR. SCOBEL: Yes. Yes. I'm assuming that  
22 it's 100 percent of that decay heat so it's not just  
23 the metals. The initial masses of the metal involved  
24 in the reaction is 3,000 kilograms of stainless steel  
25 because that is actually what's down there already,

1 and 7,000 kilograms of zirconium because that's what  
2 I can calculate could potentially be molten at the  
3 time when you are relocating oxide.

4 That's the unfrozen zirconium that would  
5 be in the system somewhere. I'm not even saying how  
6 it got down there because it doesn't really have a  
7 pathway that we can figure out but just assuming that  
8 it went.

9 So what you come up with are properties of  
10 a bottom metal layer that has a volume of 1.53 cubic  
11 meters. It's got a height of a little over half a  
12 meter. These are the masses that you get when you  
13 react it based on the 40 percent uranium. The power  
14 density in this layer is 1.38 megawatts per cubic  
15 meter.

16 MEMBER RANSOM: Can you clarify a little  
17 bit for me, you do have an offside layer you're  
18 talking about sitting on top of this metallic layer.

19 MR. SCOBEL: This is the bottom metal  
20 layer, yes.

21 MEMBER RANSOM: And it includes part of  
22 the fission products or not?

23 MR. SCOBEL: Yes, there are fission  
24 products. You mean in the metal layer?

25 MEMBER RANSOM: In terms of this energy

1 source. Right.

2 MR. SCOBEL: I'm assuming that a lot of  
3 the fission products went with this metal layer.  
4 That's what I'm assuming. A conservative lot.

5 MEMBER RANSOM: So it does generate -- it  
6 doesn't have internal heat generation as well as being  
7 conducted through it, I guess.

8 MR. SCOBEL: Yes. Actually it does not  
9 have heat coming to it from the oxide layer.

10 MEMBER RANSOM: Does not?

11 MR. SCOBEL: It does not. It's putting  
12 heat into the oxide layer.

13 MEMBER RANSOM: I'm not sure I understand  
14 the model. The oxide layer has no fission products in  
15 it?

16 MR. SCOBEL: No. The oxide layer is being  
17 heated, too. The metal layer is hotter by a couple  
18 hundred degrees.

19 I don't know if you care about seeing  
20 equations but these are the equations. You get these  
21 equations. If there's equations for the conduction  
22 layer this is through the metal itself. This is  
23 through the vessel wall. Then in the convection layer  
24 there's a nestled number. This comes out of some  
25 ACOPO tests that were published separately from the

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1 DOE report.

2 MEMBER KRESS: And for the Raeli number  
3 you just use the thickness.

4 MR. SCOBEL: For the Raeli number you use  
5 the thickness of the -- yeah. In fact, the Raeli  
6 number, this is where the height of the convecting  
7 layer is and the Raeli number contains the height of  
8 the conducting layer. You have to vary those heights  
9 to --

10 MEMBER KRESS: You're reiterating on  
11 those.

12 MR. SCOBEL: You're reiterating on the  
13 heights to converge on the temperature so you converge  
14 on that temperature.

15 MEMBER KRESS: I see.

16 MEMBER RANSOM: What is the internal heat  
17 generation term?

18 MR. SCOBEL: That was the 1.38 megawatts  
19 per cubic meter.

20 MEMBER RANSOM: I mean, I don't see any --

21 MR. SCOBEL: Oh, it's in the Raeli number.  
22 It's here and it's in the Raeli number. The Raeli  
23 number contains the internal heat generation number.  
24 Can I help you?

25 MEMBER RANSOM: No. I was just -- I don't

1 know. It would take me some time to look into it to  
2 see if you included conduction through the conduction  
3 layer as well as internal heat generation in the  
4 layer.

5 MR. SCOBEL: Yes. That's why you get this  
6 quadratic term for the conduction.

7 MEMBER KRESS: That assumes it's  
8 completely insulated on top.

9 MR. SCOBEL: Well, yeah. Because the  
10 layers have the same temperature, then it's insulated  
11 on the bottom of the convecting layer and on the top  
12 of the conducting layer. When you do that you get the  
13 peak heat flux to the vessel wall is 415 kilowatts per  
14 square meter.

15 The CHF down there is 640 and that's based  
16 on ULPU 4. ULPU 5 it's even higher just to let you  
17 know. That's a  $q/q_{CHF}$  of 0.65. We still have  
18 bounding results and still have a margin to failure  
19 with these assumptions. That's that.

20 Then if you look at the same assumptions  
21 with respect to how much metal you depleted from the  
22 metal layer by sinking these bounding -- what I would  
23 consider to be bounding amounts of the metals to the  
24 bottom metal layer --

25 MEMBER KRESS: Those wouldn't have any

1 heat in them.

2 MR. SCOBEL: Sorry?

3 MEMBER KRESS: No heat in them.

4 MR. SCOBEL: Yes. With no heat in them.  
5 I'm not reducing the heat to the metal layer. I do a  
6 bounding metal layer heat flux. I get a bounding  
7 metal heat flux of 1578. That's higher than what I  
8 got before because I have a thinner metal layer.

9 The qchf is 1875 there based on ULPU  
10 Configuration 4. Once again, ULPU Configuration 5 is  
11 higher. Based on this number I'm at 84 percent of the  
12 margin to failure so I still have bounding result with  
13 margin to failure.

14 MEMBER ROSEN: The question was have you  
15 considered alternative models and you have that you  
16 have shown to us very briefly, of course. Thank you  
17 for that answer.

18 MR. SCOBEL: You're welcome. Thank you  
19 for asking the question.

20 MR. SNODDERLY: The committee will need a  
21 copy of those slides for the record. Thanks.

22 Why don't we try to spend 15 minutes on  
23 the ex-vessel phenomena to help the committee to  
24 understand that you have done some analyses to address  
25 the fact that if, indeed, in fact the melt would be to

1 go ex-vessel, you've done some studies so I think it's  
2 important for them to hear about that.

3 MEMBER KRESS: Is this FCI?

4 PARTICIPANT: FCI, high-pressure melt,  
5 CCI.

6 MEMBER KRESS: Okay. NCCI.

7 MR. SCOBEL: Well, just to say, we looked  
8 at all these severe accident phenomena in-vessel fuel  
9 coolant, high pressure, hydrogen generation, detention  
10 to fission flame, heating the wall, containment over  
11 pressure by decay, which we talked about some before.  
12 Reactor vessel integrity which is related to IVR. Ex-  
13 vessel fuel cooling interactions, core concrete  
14 interactions, and equipment survivability during a  
15 severe accident.

16 In-vessel fuel cooling interactions.  
17 There was a ROAM assessment that was done for AP600  
18 that was called lower head integrity under steam  
19 explosion loads. It showed a very large margin of  
20 failure, like 300 times the strength needed to  
21 withstand the in-vessel steam explosion. We have  
22 actually extended these conclusions to AP1000 because  
23 conservatively we are expecting similar debris  
24 relocation pathway.

25 We don't expect a massive bottom failure

1 to relocate the entire core at one time into the lower  
2 head. The sideward pathway gives you the largest mass  
3 flow rate at one time. If you were to assume that it  
4 came out through the holes in the reflector, it's a  
5 very limited flow pathway. We have a similar debris  
6 relocation pathway with similar debris flowrate into  
7 the same geometry.

8 MEMBER KRESS: But you have a higher  
9 fraction.

10 MR. SCOBEL: Actually we don't because the  
11 initial collapse of the pool is ceramic because the  
12 metals would be drained before melting through the  
13 core barrel.

14 MEMBER KRESS: The ROAM process assumes  
15 some sort of energetic conversion factor of .03?

16 MR. SCOBEL: Actually, I don't recall  
17 that. The modeling that was done in AP600 was all  
18 done with PM-ALFA and S-POZEM models that were really  
19 incredibly critically reviewed by the staff, if you  
20 remember.

21 Mike, you were head of that, right?

22 It was all based on testing program that was  
23 done specifically for that AP600 ROAM. That's my  
24 politician answer to the question. I don't know what  
25 the conversion factor was. We rely on the AP600

1 results. Since we had so much margin to failure, we  
2 have a similar type relocation that is no different  
3 for AP1000 for in-vessel steam explosion.

4 High pressure core damage, we talked about  
5 how those were treated earlier so if I can just go on.  
6 You want to talk about hydrogen?

7 MEMBER KRESS: Does your hydrogen source  
8 stem from MAAP?

9 MR. SCOBEL: Actually, we used MAAP but we  
10 generated like probability distributions and  
11 accentuated MAAP results to be conservative like for  
12 detonation considerations. I could say, yes, it was  
13 based on MAAP but it wasn't --

14 MEMBER KRESS: But you let the experts do  
15 the distribution with it.

16 MR. SCOBEL: Yes.

17 MEMBER KRESS: Could be high or low but  
18 just use that as a guide.

19 MR. SCOBEL: Yes. I want to cover  
20 something about diffusion flames. We were talking  
21 about diffusion flames and hydrogen being released  
22 through the IRWST. We did make an improvement to the  
23 plant response to how hydrogen would be channeled  
24 through the IRWST and released to the containment.

25 There are vents all the way around the

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1 IRWST that balance the loads when you have a design  
2 basis released to the IRWST which is based on  
3 saturated conditions in the pool and then like a full  
4 blow-down of the ADS into the IRWST.

5 Under normal conditions it's not  
6 saturated. It's subcooled and you don't have such  
7 large releases. There are vents that are along the  
8 steam generator wall that are well away from the  
9 containment wall so we have decided that under low  
10 delta-P situations, what you would get when you are  
11 releasing hydrogens through the IRWST, that these  
12 vents would preferentially open over the vents along  
13 the wall to release the hydrogen away from the  
14 containment shell so you don't have the issue related  
15 to diffusion when heating the containment shell.

16 MEMBER KRESS: On what basis do you assume  
17 that the hydrogen preferentially will go through these  
18 vents?

19 MR. SCOBEL: These vents are springloaded  
20 to keep them closed and these aren't. They kind of  
21 flop open and stay open under pressure. And they open  
22 at a lower delta-P than the springloaded vents do.

23 MEMBER KRESS: If they are springloaded  
24 they don't overcome the spring.

25 MR. SCOBEL: Yes. If you're venting from

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1 these vents, then these vents don't open.

2 MEMBER KRESS: And you have ignitors  
3 somewhere in there?

4 MR. SCOBEL: Yeah, there's some ignitors  
5 inside the IRWST. There are ignitors like all over  
6 next to the vents and all through the containment.

7 MEMBER KRESS: And concentrations determine  
8 that it's a diffusion flame instead of a detonation?

9 MR. SCOBEL: Yeah. Yes. Inside here you  
10 get -- if the hydrogen release is into the IRWST.

11 MEMBER KRESS: This is looking down on top  
12 of the IRWST.

13 MR. SCOBEL: Yes, this is looking down on  
14 top. I should point out this is also a low  
15 probability event because if you have stage 4 ADS,  
16 that would be the preferential pathway to release  
17 hydrogen. It's inside the compartment. The steam  
18 generator doghouses it. It's shielded away from the  
19 walls.

20 If, in fact, you have stage 4 ADS  
21 available, you will be releasing hydrogen away from  
22 the containment wall anyway. This will be where it's  
23 going. It's only in the event that you don't have  
24 stage 4 ADS open that you have releases through the  
25 IRWST into the containment so it's not a dominant

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1 sequence but it's a consideration for defense in  
2 depth.

3 MEMBER ROSEN: Also if you release it  
4 through ADS 4 you'll have ignitors in the  
5 compartments.

6 MR. SCOBEL: Yes. There are ignitors all  
7 through the containment doghouses. I have ignitor  
8 placement diagrams if you would like to see. There  
9 were specific criteria for placing ignitors near all  
10 potential release points of hydrogen with a specific  
11 distance between them to prevent flame acceleration.

12 You had to have double coverage with two  
13 trains of power. Everything is double covered and in  
14 the loop compartments, in the PXS compartments at the  
15 exit stall to those compartments and in the upper  
16 compartment.

17 For ex-vessel steam explosion, which we  
18 consider to be prevented by in-vessel retention of  
19 core debris, we had an assessment that was done for  
20 the AP600 that was a hinged failure of the lower head  
21 into a partially flooded cavity since this was our --  
22 is our primary failure mode for the reactor vessel.  
23 We are expecting a similar vessel failure for the  
24 AP600.

25 The hinged vessel failure of the lower

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1 head is a huge flow rate of molten debris. We have a  
2 similar geometry, although the AP1000 vessel is closer  
3 to the floor which results in like a higher water  
4 level on the vessel with respect to the debris and  
5 what not.

6 If you have a hinged vessel failure, we  
7 expect similar masses, similar conditions, and similar  
8 geometry so we just said we've already done a steam  
9 explosion analysis for that configuration so we're  
10 just extending those conclusions to AP1000.

11 MEMBER KRESS: In this case wouldn't you  
12 have more metal?

13 MR. SCOBEL: Well, AP600 was metal as  
14 well. It's like the same --

15 MEMBER KRESS: Same faction of metal.

16 MR. SCOBEL: Yes.

17 MEMBER KRESS: It's the metal that causes  
18 it to have a problem.

19 MR. SCOBEL: Yes.

20 MEMBER KRESS: Is the calculation made  
21 that showed that it failed containment or not failed  
22 containment?

23 MR. SCOBEL: It did not fail the  
24 containment. It damaged the cavity pretty good but it  
25 didn't fail the containment.

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1                   MEMBER KRESS: You're saying that AP1000  
2 wouldn't fail containment.

3                   MR. SCOBEL: We're extending that  
4 conclusion to AP1000, yes.

5                   MEMBER SHACK: Is it better or worse  
6 because you have a higher design pressure in there in  
7 the AP1000? Right?

8                   MR. SCOBEL: We didn't take credit for that.

9                   MEMBER KRESS: Actually, you might be better  
10 off because you expect the same sort of energetics,  
11 the same mass material. It's the same metal and you  
12 get the same sort of energetics. You've got more  
13 water. If you've got too much water, it actually  
14 helps. You're probably better off with AP1000 than  
15 you were in AP600. A bigger containment volume,  
16 higher pressure.

17                   MEMBER SHACK: Bigger is always better.  
18 Right?

19                   MEMBER ROSEN: Let's pick it up.

20                   MR. SCOBEL: Okay. The core concrete  
21 interaction. This is another ex-vessel phenomena  
22 prevented by in-vessel retention. We looked at two  
23 vessel failure modes, hinged failure and a localized  
24 failure. The hinged failure tends to spread the  
25 debris.

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1                   The localized failure tends to pile the  
2 debris up under the reactor vessel and not spread. We  
3 looked at two concrete types, limestone and basaltic,  
4 so that in the event we decide we want to use either  
5 one, we're not limited by the analysis. Our success  
6 criteria was the basemat remained intact for 24 hours.

7                   It was done with MAAP 4 and the minimum  
8 time to basemat failure in the analyses with all the  
9 different kinds of concrete was 2.8 days to melt  
10 through the basemat. In all of our cases the basemat  
11 melt through occurs before you over-pressurize the  
12 containment with noncomencable gasses.

13                   MEMBER KRESS: You used MAAP 4 to consider  
14 retransfer to the water on top?

15                   MR. SCOBEL: Yes, but we limited the  
16 amount of water on top like we would for our normal  
17 vessel failure case so it dried out pretty quickly  
18 actually.

19                   That's another thing actually. To do this  
20 analysis we limited the amount of water that was  
21 available at the initial vessel failure. Under normal  
22 circumstances that water would actually recycle back  
23 to the cavity.

24                   MEMBER KRESS: It would condense on the --

25                   MR. SCOBEL: Yeah. It would condense on

1 the shell. We subverted that process so that it  
2 remained dry. This was a dry calculation.

3 MEMBER KRESS: Radiation off the top and  
4 down through the cavity.

5 MR. SCOBEL: Those were the things that  
6 you specifically wanted to see. Equivalent  
7 survivability, I believe, is my last slide. Are there  
8 any other severe accident issues that you would like  
9 to discuss as I would be happy to do so?

10 MEMBER ROSEN: Is this the end of your  
11 prepared remarks or how much more time do you need?

12 MR. SCOBEL: I'm done.

13 MEMBER ROSEN: Completely done. And Selim  
14 is going to come up now?

15 MR. SCOBEL: Selim is done now.

16 MEMBER ROSEN: So we're all done.

17 MR. SCOBEL: We're done and the only thing  
18 left at the end of the day would be talk about the  
19 next steps for future meetings.

20 MEMBER SHACK: Could you say a couple  
21 words about the dry PCS cooling?

22 MR. SCOBEL: Sure.

23 MEMBER SHACK: That's for all sequences  
24 we're talking?

25 MR. SCOBEL: Okay. Yes.

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1                   MEMBER SHACK: You've got the PCS cooling  
2 here so we'll buy that. It was the dry one that I was  
3 interested in.

4                   MR. SCOBEL: Dry PCS cooling is sufficient  
5 to prevent containment failure for at least 24 hours -  
6 - it's actually more than that -- based on our success  
7 criteria which is the containment fergility curve.  
8 Under nominal conditions like nominal containment the  
9 temperature outside, we don't expect any failure  
10 probability at all.

11                   Now, conservatively if you take ANS decay  
12 heat plus 2 sigma and an outside temperature of 115  
13 degrees, we came up with a failure probability of two  
14 percent at 24 hours. In fact, we used that number  
15 conservatively in the PRA as our containment failure  
16 probability at 24 hours if you don't have PCS cooling.

17                   That could have been -- we could have made  
18 it zero and then made that an uncertainty calculation  
19 but it really wouldn't have shown up that way either.  
20 It doesn't show up anywhere even with the 2 percent  
21 because PCS water reliability is so good and we didn't  
22 even credit all the capability of that system. It was  
23 just easier to just go the conservative route, take  
24 the hit on 2 percent.

25                   MEMBER KRESS: This decay heat is all

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1 going into steam. Right?

2 MR. SCOBEL: The decay heat is all going  
3 into steam. When we do these calculations we actually  
4 cool the core because that maximizes the heat load to  
5 the containment and gives you the earliest time for  
6 containment failure.

7 MEMBER KRESS: Heat transfer on the  
8 outside air duct, is that what's controlling the --  
9 you've got condensation on the inside?

10 MR. SCOBEL: The end transfer on the  
11 outside is controlling because you don't have the  
12 evaporation. You just have the convective cooling of  
13 the flow through the PCS annulus. Failure is by over-  
14 pressurization. Anything else?

15 MEMBER ROSEN: No. I think unless the  
16 members have any further questions, I don't see any  
17 interest in that. Any further comments from any  
18 member of the audience?

19 If not, we have a session that begins at  
20 1:15 this afternoon if I'm not mistaken with the staff  
21 taking over. NRC staff presentation begins at 1:15.  
22 I assume Westinghouse will stick around for that and  
23 we'll see you all back here then at 1:15.

24 (Whereupon, off the record for lunch to  
25 reconvene at 1:15 p.m.)

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

2 1:17 p.m.

3 MEMBER ROSEN: Output for the research  
4 report. Make sure you take it with you and do what  
5 you are supposed to do based on that. I have now  
6 fulfilled my obligation to Dr. Ford.

7 MEMBER SHACK: Let me just mention that if  
8 you have any editing comments, either send them to me  
9 or give me a marked up copy so I can include those  
10 when I'm doing the lowly-paid editor's job.

11 MEMBER ROSEN: Okay.

12 MEMBER SIEBER: Is this going to be sent  
13 to us by e-mail attachment or anything?

14 MEMBER ROSEN: I don't know. You would  
15 have to ask Peter.

16 MEMBER SIEBER: That would be great if we  
17 would and it's easier for you and me.

18 MEMBER ROSEN: Yeah, that's a good thought  
19 because I'm going to have to revise parts of this so  
20 if I had it electronically it would be easier.

21 MEMBER SIEBER: Yeah. It makes everything  
22 much simpler.

23 MEMBER SHACK: I think Peter is intending  
24 to do that.

25 MEMBER ROSEN: Okay. Let's get on with

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1 the afternoon's entertainment. Mr. Palla.

2 MR. PALLA: Okay. Hi. I'm Bob Palla.  
3 I'm in the Probabilistic Safety Assessment Branch of  
4 NRR. We are responsible for reviewing both the Level  
5 2 PRA. You heard about the Level 1 yesterday. I'm  
6 going to speak to the Level 2 and 3 portions of the  
7 PRA and the severe accident analyses that are part of  
8 the application in support of the PRA.

9 As background, the review in these areas  
10 is split between the Office of Nuclear Reactor  
11 Regulation and our Office of Research. We are  
12 reviewing the Level 2 and 3 PRAs within NRR but in the  
13 area of severe accidents we rely heavily on the Office  
14 of Research to perform the more in depth review of the  
15 specific underlying analyses of severe accidents and  
16 some of the reviews of the phenomenological analyses.

17 Richard Lee will present a brief  
18 discussion of the research activities as soon as I'm  
19 finished here. The sooner the better. You get to  
20 hear the real substantial information.

21 Our review objectives and approaches  
22 basically as Nick Saltos outlined it to you yesterday,  
23 we want to look at PRA in terms of is the quality  
24 sufficient to support the intended use. Does it  
25 sufficiently guide the insights regarding the safety

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1 of the design and what's important to the design.

2 We want to also focus on the similarities  
3 and the differences between AP600 and AP1000 for help.  
4 Basically to provide some efficiency in the review.  
5 We will be looking most closely at these areas of  
6 differences like the increased power levels and how  
7 that influences in-vessel retention, molten debris  
8 masses that could affect core concrete interaction and  
9 these kind of aspects of the model. We'll look at the  
10 impacts that they would have on the major results.

11 Now, what I've got on the remainder of  
12 this slide and on the next slide is in essence a high-  
13 level summary of the areas of concern that we  
14 addressed in the request for information that we  
15 transmitted to Westinghouse.

16 This presentation might have been a little  
17 more meaningful if it would have preceded the  
18 presentation by Jim Scobel because then you might pick  
19 up on those things that were presented that were  
20 specifically in the areas that we were asking for.  
21 I'll kind of point it out here just what the key areas  
22 are. Many of these areas you've already heard Jim  
23 explain analyses in part but then we'll answer our  
24 questions.

25 It's kind of a broad-sweeping issue that

1 we had with the AP1000 submittal was that when it came  
2 to issues like hydrogen generation and mixing and the  
3 probability of distributions used within the Level 2  
4 analysis. Thermal loads on the vessel for example,  
5 the in-vessel and ex-vessel fuel cooling interactions,  
6 as well as the fission product release fractions.

7 All of this information was in the AP  
8 vessels. We didn't receive AP1000 specific analyses  
9 on those issues. Rather, what Westinghouse approached  
10 in the initial supplemental was that the composition,  
11 the masses, the super heat that was calculated for  
12 AP600 is similar and similar enough to AP1000 that the  
13 results were bounding.

14 I guess in recognition of the power  
15 differences between the plants and the changes that  
16 were made with reactor vessel internals like the  
17 shroud replacing the reflector, and also some of the  
18 information in the AP1000 submittal was suggestive of  
19 the possibility that accident progression is quite a  
20 bit more drastic than AP1000 because of AP600.

21 For all of those reasons we were skeptical  
22 in accepting at face value without some kind of  
23 justification or analysis to support the statement  
24 that the various aspects of the analysis were directly  
25 applicable.

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1 Jim explained much of this today. He  
2 presented AP1000 specific calculations in several of  
3 these areas. We expect that's largely going to be  
4 responsive to the kinds of issues that we were  
5 concerned about. We'll be looking for closely at that  
6 information.

7 MEMBER SHACK: The responses you have to  
8 the RAIs, or at least Westinghouse thinks they have  
9 answered these questions.

10 MR. PALLA: We have not had a feedback  
11 yet. We are still early in the process of looking  
12 through. We've given them a quick look. I think  
13 Richard may be able to speak a little bit more  
14 definitively. I think they are a little further along  
15 in their reviews.

16 In some regard, some of the areas that  
17 they are looking at are the same things that we're  
18 looking at. In-vessel retention we're kind of both  
19 looking at it, but we look to them to provide the real  
20 horsepower for the details.

21 For example, the RASPLAV and the MASCA  
22 test results, are they applicable or not. Are they  
23 prototypic. This is something that Research and Ali  
24 Behbahani is much more familiar with so we will be  
25 relying on them.

1 I don't want to prejudge something as  
2 being a resolved issue if I think it's closed, but  
3 then they upon further thought and reflection on it  
4 might think there are still some additional details  
5 there. I'm going to be kind of noncommittal to saying  
6 things are resolved. The state that are, at least in  
7 my mind, is that we are still looking at these things.

8 Applicability of AP600 results. We now  
9 have AP1000 specific calculations that we will be  
10 looking at so that hole has been plugged. In the area  
11 of external reactor vessel cooling, as Jim mentioned,  
12 the same logic as was used in AP600 has been used for  
13 AP1000.

14 Basically if the reactor cavity is  
15 successfully flooded with a different success criteria  
16 -- there's been a tweaking on the success criteria --  
17 and if the RCS is fully depressurized, the debris  
18 stays in-vessel.

19 Now, we've looked at that for AP600 and we  
20 concluded in our review for AP600 that reactor in-  
21 vessel integrity is likely to be maintained but we  
22 acknowledged relatively large uncertainties in the  
23 processes involved. They are very complex.

24 These attempts to model this situation  
25 experimentally is quite difficult, the design

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1 experiments that faithfully reproduce it. One could  
2 argue whether the results are prototypic or not. We  
3 see large uncertainties in being able to predict  
4 things like the heat fluxes.

5 The general heat transfer expressions in  
6 and of themselves have uncertainties associated with  
7 them. In our review of AP600 we sponsor some work at  
8 INEL where they looked at alternate debris bed  
9 configurations such as the one that Jim kind of  
10 touched on that in his last few slides where he  
11 described the metallic layer that could sink to the  
12 bottom if sufficient uranium is dissolved and it  
13 becomes more dense.

14 You could have a heat-producing layer on  
15 the bottom. We postulated a couple of other  
16 scenarios. A thinner layer on the top, thinner than  
17 what was proposed in the Theofonous report.

18 We also postulated the possibility of kind  
19 of a sandwich steel layer where debris was both below  
20 and above the steel layer heating it from above and  
21 below. Perhaps it's a variation on this focusing  
22 affect.

23 But in recognition of all of those  
24 uncertainties, we think that it was prudent, and we  
25 did in the AP600, require additional calculations,

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1 deterministic calculations of ex-vessel phenomena.

2 So while within the PRA we have accepted  
3 the basic assumption that the debris stays in-vessel  
4 given that the two major success criteria are met, we  
5 did require, and similarly for AP1000, we are  
6 requiring ex-vessel calculations to be done to assure  
7 that in the event that the debris goes ex-vessel that  
8 the containment is not directly challenged.

9 With regard to each of these items here,  
10 reduced margins to CHF, impact of uncertainties, the  
11 work that we had done on AP600 indicated that while we  
12 expected things to stay in-vessel, the margins, we had  
13 much smaller margins because we had a model that  
14 solved the same governing equations as in the ROAM  
15 report but propagated through both parametric  
16 uncertainties, uncertainties in the correlations, and  
17 also looked at these alternative debris bed  
18 configurations.

19 When you take that additional information  
20 on balance, you would say chances are if you have that  
21 kind of configuration, it looks like you'll stay in-  
22 vessel but the margins are less.

23 Then if you have these other  
24 configurations, we're not so sure. Again, we went to  
25 this balanced approach where there is a reliance on

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1 in-vessel retention but yet we cover all the bases by  
2 looking at the consequences in terms of pressure loads  
3 if you go ex-vessel.

4 MEMBER SIEBER: One of the issues if you  
5 go ex-vessel is that you're going to end up going into  
6 this big pool of water that surrounds the vessel. The  
7 Westinghouse calculation basically says that there's  
8 plenty of margin for steam explosion. Have you looked  
9 at how much margin there really is?

10 MR. PALLA: Yeah. We're in the process of  
11 looking at it. Richard may talk to that if he's got  
12 some time. With regard to recent experimental work,  
13 the work that you heard Jim describe, the RASPLAV and  
14 the MASCA results and their applicability, we had a  
15 basic question given we've got several years between  
16 AP600 and now.

17 We've learned a lot of those tests have  
18 been completed in the intervening years. We ask what  
19 are the implications? What does that say about this  
20 stratified layer? We thought it may actually be that  
21 those tests are not as prototypic as one might hope  
22 for but there are insights that we want to make sure  
23 that we bring to bear on this whole question.

24 Another issue we raised was the thinned  
25 RPVs. Jim mentioned it. You look at the heat fluxes

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1 and the heat fluxes determine theoretically the  
2 thickness of the steel vessel that you're left with.  
3 I think the number was 36 times the amount required to  
4 accommodate the deadload.

5 If you look at the pressurization that  
6 might occur, if you have a small pressure spike within  
7 the vessel upon a reflood, for example, it looks like  
8 about 35 PSI might be enough to eat up that margin  
9 that you have. 35 PSI integrated over the cross-  
10 sectional area of the vessel and carried over a small  
11 thickness gives you what we thought to be some  
12 concerns regarding just pressure oscillations in the  
13 vessel being a structural load.

14 That's been addressed with some arguments  
15 based on expected pressurization rates for a couple of  
16 different situations. We have an REI response. We  
17 haven't really fully reviewed its adequacy yet.  
18 Design a thermal insulation is something, as Jim had  
19 mentioned again.

20 For AP600 the heat transfer situation is  
21 basically an open free pool of water that just bubbles  
22 freely. The details of the design of the insulation  
23 were not critical because there was no attempt to  
24 really optimize critical heat flux.

25 What we see with AP1000 is essentially the

1 need to optimize that design, to maximize the CHF  
2 because that's necessary to accommodate the decay heat  
3 loads.

4 The way that one would take the  
5 experimental data, and perhaps, I guess, the ULPU  
6 Configuration 5 would be the best source of that data,  
7 but one has to determine the specifications that one  
8 would design this insulation system for to ensure that  
9 it maintains its structural integrity under the  
10 flooded up conditions with the kind of flows and  
11 pressure oscillations that one could see. If you've  
12 ever had a chance to look at the ULPU test facility,  
13 one thing that is pretty impressive is just the large  
14 degree of pressure oscillations that is apparent from  
15 looking at the test rig. There's like a plenum below  
16 the heated blocks. It basically has flat sides to it.  
17 When that test gets chugging away, you can just watch  
18 the sides of that little plenum chamber kind of  
19 oscillating.

20 During the AP600 review it became an issue  
21 of where are you going to get the pressure data from  
22 to design this insulation and how does it scale. It's  
23 on the table here. It's still a question that we are  
24 going to have to be dealing with.

25 We had some questions about hydrogen

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1 control. We questioned the diffusion flame mitigation  
2 strategy. I think there was maybe a bit of confusion  
3 in the application where it appeared that Westinghouse  
4 was relying on a creep rupture calculation that they  
5 had done for AP600 as part of the mitigation strategy  
6 for AP1000 as well.

7 We question whether they really intended  
8 to do that and they have given us clarification. In  
9 essence the strategy does not rely on creep rupture.  
10 Rather, it has the hooded IRWST vents that will close  
11 and redirect the hydrogen to the more central areas of  
12 containment where it won't challenge the shell.

13 We asked some questions about ignitor  
14 placement velocity and the effectiveness. We had some  
15 concerns because the same number of ignitors are  
16 covering a larger volume. We wanted to make sure that  
17 there isn't the possibility to have increased  
18 concentrations as a result of the greater distances  
19 between that. We got a response on it and we'll be  
20 looking at that more closely.

21 Like in AP600 there is a nonsafety related  
22 containment spray header in this design. Kind of a  
23 follow-on from the AP600 carryover.

24 MEMBER SHACK: They didn't say much about  
25 it.

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1 MR. PALLA: No. In fact, I thought that  
2 they might have included a top event in the event tree  
3 to deal with the effects of the spray that it might  
4 have. It has both potentially negative effects as  
5 well as the obviously positive effects of fission  
6 product scrubbing, but it could de-inert the  
7 containment when you were otherwise thinking it might  
8 be better to be inert sometime.

9 If you operate the sprays, you could  
10 create a flammable situation. It's really the same  
11 question that we asked on AP600. It wasn't modeled in  
12 the event tree there either. It's still not modeled  
13 here. We just want to make sure that there's nothing  
14 -- it's not going to create any kind of a risk or  
15 pervasion on the results.

16 Direct containment heating would appear to  
17 not be an issue. Admittedly the likelihood of high  
18 pressure melt events is quite small in this design but  
19 there is a little bit of a history behind the direct  
20 containment heating and how one deals with it in  
21 design certification.

22 I guess in 1993 in SECY 93-087 there is  
23 kind of a staff policy paper that went up to the  
24 commission. It said the staff's view is that advanced  
25 reactor vendors should design the cavity with features

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1 that would reduce the amount of debris that is  
2 disbursed to the upper containment and should provide  
3 depressurization systems. We have this qualitative  
4 criteria out there.

5 Subsequently around 1996 Sandia and the  
6 Office of Research completed work on a methodology to  
7 quantify the pressure loads from DCH events. When we  
8 reviewed AP600 Westinghouse in response to staff  
9 request provided quantitative assessment of the loads  
10 consistent with that methodology.

11 Now, for AP1000 we were expecting that one  
12 could make arguments as they had made arguments about  
13 masses in compositions being comparable to AP600. We  
14 didn't get that kind of an argument. The argument was  
15 we need those items specified in SECY 93-087. We got  
16 a depressurization system and we got the cavity that  
17 has these kind of features the staff was looking for.

18 We asked for a DCH mechanistic calc. We  
19 didn't get one yet so we'll probably be asking again  
20 to do that. We will at least have some dialogue on  
21 it. We would at least like to know that the pressure  
22 loads are comparable to the AP600.

23 With regard to core concrete interactions,  
24 one thing that's different as a result of the design  
25 being the higher power level, higher core masses, same

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1 exact footprint as far as the reactor vessel and the  
2 reactor cavity so naturally the debris debts are going  
3 to be different in the two designs.

4 In the initial application it did not  
5 indicate that there was any change being made to the  
6 cavity. In particular, there's a sump within the  
7 cavity. The sump is located -- the reactor vessel is  
8 on one side of the cavity. The sump is on the other  
9 side.

10 There's actually like an intervening wall  
11 with a doorway past that wall that goes into the other  
12 part of the cavity. The sump is on the far side.  
13 There's a curb around it. The curb was designed to be  
14 at a height such that I think the full core could  
15 reside in the cavity and not overflow the curb. That  
16 curb probably wasn't changed from AP600.

17 Analyses were submitted in the application  
18 that argued that it was not an issue. Debris in the  
19 sump would not be an issue but that was predicated on  
20 an assumption that metallic and oxide components of  
21 the debris would separate and that the metallics -- if  
22 you look at what ended up on the far side it would be  
23 primarily metallic. If you looked at what was below  
24 the reactor vessel it would be primarily oxidic.

25 Being skeptical, naturally, we thought

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1 what if it wasn't that way. What if it was an  
2 uniformly distributed homogenous mixture that's spread  
3 out. We expected to see some calculations of that.  
4 We didn't get that yet. We did get an indication that  
5 the design has been changed.

6 The sump curb has been increased to  
7 accommodate what I think would be the full core, the  
8 fully inventory. We still have some questions about  
9 the core concrete interactions, the effect of the  
10 deeper depth of debris on basemat penetration.

11 The last item here is just three different  
12 areas where the application did not include the same  
13 level of information that was included in which we  
14 used in the AP600 reviews. Equipment survivability  
15 assessment was stripped of all of the details.  
16 Pressure and temperature histories have now been  
17 provided in response to that.

18 Important analyses results, some of which  
19 Jim presented, I think were lacking in the submittal  
20 but were provided subsequently.

21 CHAIRMAN APOSTOLAKIS: Who cares? Does  
22 anyone use those?

23 MR. PALLA: I just threw it in there. No.  
24 It was for completeness. What I did here was I  
25 summarized what we were asked for and now you've heard

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1 it.

2 CHAIRMAN APOSTOLAKIS: Are you going to  
3 take any action based on these results? No.

4 MR. PALLA: My point was if you looked  
5 only in the submittal, you won't find these things.

6 CHAIRMAN APOSTOLAKIS: I understand that.

7 MR. PALLA: You have to go to the RAIs and  
8 the modified and there will be an update to it. That  
9 was the only point. With that done, Richard can fill  
10 you in on the research activities.

11 CHAIRMAN APOSTOLAKIS: I mean, it's not  
12 like we're talking about --

13 MR. PALLA: It was missing information.  
14 We're not even saying there were problems in those  
15 areas. We're just saying there wasn't any information  
16 submitted.

17 CHAIRMAN APOSTOLAKIS: By the way, we are  
18 still categorizing SSCs as seculated and nonseculated.  
19 Right? I guess later you will probably consider  
20 option 2 yourself. We wonder why not now. It's  
21 because of regulations.

22 MR. LEE: Thank you. As Bob mentioned, I  
23 hate to disappoint you, Dr. Seiber. We don't have --  
24 excuse me? We haven't got the results yet for this  
25 analysis. It's about one and a half month away before

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1 we finish all this analysis.

2 I will walk you through what type of  
3 analysis we plan to do to address some of the severe  
4 accident related issues that we like to know for the  
5 AP1000 and to help in the design certification within  
6 the next two months.

7 I would like to mention that besides me in  
8 the Office of Research, there are two key persons.  
9 Dr. Basu helps us with the analysis and FCI related  
10 stuff. Also on the MELCOR concrete interactions. In  
11 the in-vessel retention, Dr. Behbahani is involved  
12 with a lot of the RASPLAV project and the MASCA, as  
13 you mentioned earlier. That is an area that we will  
14 be concentrating on plus other things.  
15 We have contracted with ERI to do these MELCOR  
16 analysis.

17 CHAIRMAN APOSTOLAKIS: With whom?

18 MR. LEE: Energy Research Institute, ERI,  
19 with Dr. Mohsen Khatib-Rahbar. As you can see here,  
20 the reason is that we are using MELCOR. Dr. Ransom  
21 earlier asked us whether you can use MAAP. MAAP  
22 doesn't give you detail on melt progression inside in  
23 the severe accident arena but MELCOR does.

24 It's comparable to the SCDAP 5. We  
25 decided we are going to use the MELCOR code to do our

1 analysis to get some of these initial conditions and  
2 mass and so we can do the other subsequent analysis.

3 The MELCOR 1.8.5 we are using now are  
4 different from the one that we used back in the AP600  
5 analysis a while ago. So we went back and we also  
6 benchmarked the new code against the previous code and  
7 looked at the results to make sure that they are  
8 comparable in terms reasonably giving the similar  
9 results. So we benchmark against AP600 first and now  
10 we modified the data for the AP1000. And that has been  
11 completed recently.

12 We also get a lot of information through  
13 Westinghouse, and also they give us the MAAP, which  
14 give us a lot of information we needed for our  
15 analysis.

16 Now, you understand that the MELCOR has  
17 some limitation in terms of doing the in-vessel  
18 retention type analysis because the model -- earlier  
19 you asked us whether we have a monitor can do the melt  
20 partitionings and whether the fission products will go  
21 to the right place.

22 We are in the process of this year  
23 implementing such a model in MELCOR but it's not  
24 available for our purpose here so we are going to do  
25 the sequence analysis, look at the melt mass

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1 composition and so forth and we are going to use a  
2 separate model to do the in-vessel retention analysis.

3 We also have the model that Jim mentioned  
4 from INEL and CRI has it. We found the same error  
5 that you did. We think that the analysis we show  
6 about looking at equivalency, that is a valid  
7 methodology that you're using. We intend to do the  
8 same thing but with the models with a hemisphere.

9 From that we are going to look into the  
10 base on what the MELCOR compilations we find. We can  
11 look at all the different type configurations. For  
12 example, if you have metal down there with oxidic  
13 melt, and then on top you have another thin layer of  
14 metallic, we can look at all those variations with a  
15 separate analysis. That is what we intend to do for  
16 the in-vessel retention questions so we can explore  
17 the whole range of it.

18 Let me show you a viewgraph that is not in  
19 your handout. These are the results from the MASCA  
20 project. There are four tests here. It started with  
21 a composition of this and these are the metal part.  
22 It ends up with a composition which this one is oxidic  
23 and this one is metallic.

24 You can look at how much is oxidized and  
25 this tells you the uranium zirconium ratio. These are

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1 the full tests. You can see that it depends on the  
2 type of additives you put in. You can see that the  
3 subsequent compositions are different.

4 That gives you some idea that even though  
5 you started off with these two material, they end up  
6 in the different configurations based on different  
7 conditions. These are the type of insights we like to  
8 look into for our in-vessel retention analysis.

9 If ACS want to listen to the start presentation from  
10 Research on MASCA in the future, we will be glad to  
11 present that to you in details.

12 The sequence that we have chosen to do the  
13 analysis, as you have seen here, are from the  
14 Westinghouse one, two, and three which are frequency  
15 dominant sequence 29, 18, and 9. We also chose one,  
16 No. 20.

17 Actually, we asked them for some more  
18 clarification on this sequence and we subsequently  
19 received some of the information but we may need to  
20 have some more. Do you have some more questions on  
21 that?

22 PARTICIPANT: There will be some minor  
23 questions.

24 MR. LEE: So there are some minor  
25 questions that I think we can clear with you. This

1 has to do with something with whether this is really  
2 drained directly into the cavity and about the IRWST,  
3 these two items here. This is really, I think, just  
4 clarification. These are the four sequences we intend  
5 to base our calculation on.

6 CHAIRMAN APOSTOLAKIS: Of course, again,  
7 I have the same problem with your description on the  
8 left of the last LOCA. The sequence that you are  
9 referring to, 18 percent of the total is just large  
10 LOCA and failure of one accumulator. It doesn't say  
11 anything about RHR or BRHR or CMT. I don't know how  
12 that would affect your calculations. That's block  
13 damage state 3BR.

14 MR. LEE: That's correct.

15 CHAIRMAN APOSTOLAKIS: Maybe you put it  
16 there for completeness.

17 MR. LEE: Yes. That's what it is.  
18 Because this is a low-pressure sequence, this is  
19 somewhere over medium and this is something high.

20 MR. KHATIB-RAHBAR: Excuse me. This is  
21 Mohsen Khatib-Rahbar. George, whatever is listed as  
22 a description of a scenario are those which are  
23 credited in the calculation. They are not just for  
24 listing those items. These are reproduced from the  
25 Westinghouse document. We are not looking at why CMTs

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1 are operating for large LOCA and similar to core  
2 damage, etc. We are taking those as given.

3 CHAIRMAN APOSTOLAKIS: Well, if I read the  
4 description of the large LOCA event tree for that  
5 sequence, they say that the core makeup tanks are  
6 insufficient so they stop part of the event. For the  
7 other sequences they are.

8 MR. KHATIB-RAHBAR: For these they are  
9 also insufficient. You go to core damage.

10 CHAIRMAN APOSTOLAKIS: Yeah.

11 MR. KHATIB-RAHBAR: Right.

12 CHAIRMAN APOSTOLAKIS: The sequence that  
13 leads to -- it's not really 18. It's 19 something --  
14 is 3BR which is the lowest one.

15 MR. KHATIB-RAHBAR: This is one of the  
16 sequences. This is the dominant one in 3BR. Exactly.  
17 It's 18 percent, I think, of the 19 percent that you  
18 have. Yes.

19 MR. LEE: So this forms the basis for our  
20 getting the initial conditions for subsequent analysis  
21 which is looking into other sensitivity analysis in  
22 the ex-vessel for MCCI.

23 In this one here we plan to use the core  
24 coat stand-alone model to do the analysis so we can do  
25 also variation because we don't really need to use the

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1 whole core to do the analysis for this one over here.

2 We also are going to look into the  
3 containment spray operation that is within MELCOR  
4 itself. The reason we are looking into this because  
5 the spray now is located -- the containment is taller  
6 so I believe the flow rate is still the same. We  
7 think the efficiency will become a little bit lower  
8 because the drop intensity will be lower and the drop  
9 calculations. Because of those two reasons. This is  
10 to look into what impact this has had on the  
11 containment loads, pressure and temperature as well as  
12 fission power scrubbing, too.

13 What I didn't mention here that we will do  
14 the FCI in-vessel, ex-vessel separately, too. For  
15 those we have many options. I think the PM-ALFA  
16 astro, we are going to use that. We also have the  
17 option to use Texas coat from the University of  
18 Wisconsin for the FCI analysis.

19 I think we expect to finish all this  
20 within about a month or so and we should be able to  
21 tell you something more by that time. I'm not too  
22 sure if you're interested in looking at these. This  
23 is the MELCOR deck. This is the vessel, the steam  
24 generators, and simulation for all the rest of the  
25 components here. This is the nodalization for the

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1 containment.

2 As a matter of fact, at this time we have  
3 already finished one of the calculations on the 3BE  
4 but we haven't looked at the results yet.

5 MEMBER RANSOM: Each one of the boxes, is  
6 that a control volume or node in MELCOR?

7 MR. LEE: Yes.

8 MEMBER RANSOM: So you have composition  
9 and what flows from one to the other?

10 MR. LEE: That's correct. For example  
11 here, if I'm correct, we didn't show all the detailed  
12 nodes in here. The five-ring model is here with the  
13 10 axle nodes. The MELCOR 1.8.5 -- MELCOR used to  
14 only have three rings and 10 axle nodes but we try to  
15 maintain only one code instead of maintaining SCDAP 5  
16 and MELCOR so we make MELCOR and improve it to be 5  
17 rings.

18 The reason is SCDAP 5 has 5 rings. When  
19 we do comparison between different type of analysis  
20 between SCDAP 5 comparison we want to have one-to-one  
21 comparison between the nodes. Now we have developed  
22 a 5-ring model for MELCOR. We can tell details of  
23 melt progression inside over here. Within this frame  
24 work we can analyze how AP1000 melt progression will  
25 look like.

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1 CHAIRMAN APOSTOLAKIS: Is this a major  
2 effort?

3 MR. LEE: Which one?

4 CHAIRMAN APOSTOLAKIS: As such you  
5 described.

6 MR. LEE: For which one?

7 CHAIRMAN APOSTOLAKIS: The whole thing.

8 MR. LEE: The model here, we started this  
9 back like in October of last year. We have an AP600  
10 deck and I think --

11 MR. KHATIB-RAHBAR: It's a few months of  
12 effort.

13 MR. LEE: We mostly converted it in two  
14 months. We did a QA on it.

15 CHAIRMAN APOSTOLAKIS: Out of curiosity,  
16 take 3BR. Frequency is 4.6 events every 100 million  
17 years. 4.6 events every 100 million reactor years.  
18 How low would you have to go for you not to do  
19 anything? Why are you doing all this? I mean, this  
20 is an incredible event. There may be two answers.  
21 One is defense-in-depth, the structure of this  
22 approach. No matter what you do in Level 1 I want to  
23 spend --

24 MR. LEE: That's right.

25 CHAIRMAN APOSTOLAKIS: The other one that

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1 you don't believe the number. Between a rock and a  
2 hard place.

3 MR. CORLETTI: Can we vote?

4 CHAIRMAN APOSTOLAKIS: I'm serious. How  
5 low does it have to go? Every billion reactor years?  
6 Where do you draw the line?

7 MR. PALLA: I guess --

8 CHAIRMAN APOSTOLAKIS: Defense-in-depth?

9 MR. PALLA: No. I was just going to say  
10 that I think what you draw from these kind of analyses  
11 -- you can argue just how many analyses do you need to  
12 do. We thought that a few analyses would be not that  
13 intense of an effort given that we were starting with  
14 a deck that was already available so relatively  
15 straightforward changes to the deck to account for the  
16 changes in the designs.

17 And then some sequences that could be used  
18 to assess and to confirm the general nature of the  
19 accident progression because you can't get wed to the  
20 exact specifics of these kinds of scenarios anyway.  
21 The uncertainties in accident progression are quite  
22 significant code to code. Even within the same code  
23 you could perturb the sequence and end up with  
24 substantial differences.

25 We would look to these as general

1 confirmation that, yeah, the calculations used as the  
2 basis for the AP600 PRA are in general agreement in  
3 terms of the order of the events and the general  
4 timing of the events.

5 CHAIRMAN APOSTOLAKIS: What you just said  
6 gives me -- makes me think of something that occurred  
7 to me this morning.

8 MR. PALLA: But you could confirm, like  
9 fission products, for example, could be confirmed.  
10 Order of magnitude confirmation. Once you've run the  
11 calculation you can do simple sensitivity studies like  
12 turn on the sprinklers and let the thing go ex-vessel  
13 and let it oblate concrete and see if you are in the  
14 same ballpark with pressurization rates, oblation  
15 depths. We didn't view it as a major sinkhole of  
16 resources.

17 CHAIRMAN APOSTOLAKIS: You just said  
18 something just now that there is uncertainty within  
19 the code, model uncertainties. I remember now -- I  
20 don't remember, I look at the figures that Jim  
21 presented this morning. You're talking about  
22 condition containment failure probability of .07, .08.

23 Based on what you just said and what I  
24 remember from 1150 this would be anywhere from zero to  
25 what? What am I learning from all this? I'm trying

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1 to understand what I'm learning from this. I'm  
2 learning nothing.

3 MEMBER RANSOM: Is it possible these are  
4 the high consequence situations? I mean, if you put  
5 it in terms of number of depths for reactor year of  
6 operation, do these contribute more than some of the  
7 others?

8 CHAIRMAN APOSTOLAKIS: I don't know. Do  
9 they? They certainly run high with respect to core  
10 damage frequency.

11 MR. BASU: George, this is Sud Basu from  
12 the Office of Research. There is a third answer. We  
13 need initial and bounding conditions for other  
14 analysis such as FCI, such as CCI. We need to do  
15 MELCOR calculations.

16 CHAIRMAN APOSTOLAKIS: CCI stand for?

17 MR. BASU: Core concrete interactions.

18 CHAIRMAN APOSTOLAKIS: Why do I have to  
19 worry about that? Selim has done such a great job.  
20 Why do I have to worry about that?

21 MR. BASU: Okay. Now, if you want to  
22 rely entirely on the frequency argument without --

23 CHAIRMAN APOSTOLAKIS: Ah, it's defense of  
24 that.

25 MR. BASU: There you go. Thank you.

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1 MEMBER SHACK: Structuralist.

2 MR. LEE: Maybe we will find out it's  
3 better than what they claim so you should worry less  
4 even about it.

5 CHAIRMAN APOSTOLAKIS: I don't worry.

6 MR. LEE: Right. I don't either.

7 CHAIRMAN APOSTOLAKIS: I'm really  
8 skeptical about the value of these numbers that we're  
9 getting at the end, even the uncertainties. It's  
10 between zero and what? Anyway, do you have anything  
11 else to say?

12 MR. LEE: No.

13 CHAIRMAN APOSTOLAKIS: Bob? Any members?  
14 Westinghouse? Thank you very much.

15 MR. LEE: Thank you.

16 CHAIRMAN APOSTOLAKIS: According to the  
17 schedule, we are going back to Mike, right?

18 MR. CORLETTI: This is Mike Corletti,  
19 Westinghouse. I don't think it's very useful to go  
20 over any more slides.

21 CHAIRMAN APOSTOLAKIS: Unless you have  
22 something interesting.

23 MR. CORLETTI: No, not really. Perhaps at  
24 this time it's just best to talk about the next steps  
25 as far as future meetings. First of all, I want to

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1 thank you all for the two days of meetings. The  
2 questions give us good insight and some more things to  
3 think about.

4 All in all hopefully we have met your  
5 expectations for providing you information. I'm sure  
6 we'll be hearing more about that if we haven't. In  
7 any event, I think the next interaction that we have  
8 with the ACRS will be, Med was just telling me, March  
9 19th and 20th which we'll have a thermal hydraulic  
10 subcommittee. I think if you look in your book I had  
11 listed -- I think it's on slide 5. No, slide 6.  
12 Maybe it's slide 7.

13 CHAIRMAN APOSTOLAKIS: Slide 7, ACRS  
14 meeting.

15 MR. CORLETTI: Yes. As far as the subject  
16 matter, I think for the thermal hydraulic do you have  
17 any input as far as additional topics for the thermal  
18 hydraulic meeting? I think that's probably a full  
19 plate with safety analysis, the issues of entrainment  
20 and the Oregon state testing that's going on. It  
21 think that's what we planned on discussing at that  
22 meeting.

23 Then I think that I show April but I  
24 believe the meeting will actually be in May, a plant  
25 subcommittee according to what Med said. There we

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1 will talk about -- I think the issues are listed.

2 Plus I think there is an additional issue  
3 of man machine interface that the committee would like  
4 to hear about as far as what our plans are for AP1000.  
5 I don't have any that can come off the list. I think  
6 the best is to talk amongst yourselves and work with  
7 Med to give me any other changes to that.

8 Then I believe we'll have a meeting in  
9 June to close out any open items that may come from  
10 that meeting, so May and June, and then have a full  
11 committee meeting in July. The July meeting we would  
12 be looking for a letter.

13 MEMBER LEITCH: One of the things in that  
14 plant system meeting -- that's not quite the right  
15 term for it -- in April or May, I guess I would like  
16 to be able to take a look at what I would call P&IDs  
17 of particularly the passive safety systems.

18 There were some P&IDs along with the CDs  
19 that you sent us on the PRA, but it seemed like there  
20 was two versions of them. One was a very, very  
21 simplified system drawing which was not useful for the  
22 purpose that I wanted to look at.

23 Then another one was a P&ID that was  
24 hopelessly compressed. It was just difficult to read.  
25 I'm looking for something that is kind of in between

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1 that other than hard drawings how to do that, I guess.

2 MR. CORLETTI: Is it that you would like  
3 a -- we could submit our P&IDs to review a bigger  
4 version of the compressed one, of the detailed one?

5 MEMBER LEITCH: Yeah, I think that would  
6 satisfy my need. It wasn't that it had too much  
7 information. It was just --

8 MR. CORLETTI: It was 11 by 17 version of  
9 a --

10 MEMBER LEITCH: Actually it was 8 1/2 by  
11 11.

12 MR. CORLETTI: Okay. We have half-size  
13 drawings. The DCD has an 11 by 17 version. Do you  
14 have a hard copy of the DCD?

15 MEMBER LEITCH: No.

16 MR. CORLETTI: So you probably have the  
17 CD.

18 MEMBER LEITCH: CD, yeah.

19 MR. CORLETTI: What we submitted is 11 by  
20 17 which maybe we can get a copy of that, Jerry?

21 MR. WILSON: This is Jerry Wilson. Yeah,  
22 there are. Mike, don't you have hard copies?

23 MR. CORLETTI: We should be able to check  
24 with Med and see if we have the hard copy. I'm pretty  
25 sure we do. If we don't, we can work with --

1 MR. EL-SADAWY: We just have one hard copy  
2 of the whole DCD. What we had is the CDs that all  
3 members received.

4 MR. CORLETTI: How about if we prepare a  
5 package of information that is a docket of information  
6 that is the P&IDs but we'll just collect it in a  
7 package of 11 by 17 drawings and we can furnish X  
8 amount of copies.

9 MEMBER LEITCH: That would be helpful to  
10 me.

11 CHAIRMAN APOSTOLAKIS: Are you done, Mike?

12 MR. CORLETTI: I'm done.

13 CHAIRMAN APOSTOLAKIS: Thank you very  
14 much. Thank you and your colleagues for taking the  
15 time.

16 MR. SNODDERLY: George, this is Mike  
17 Snodderly. I just wanted to thank Mike Corletti for  
18 all his support in preparing this material for the  
19 committee and the presentation. And also I wanted to  
20 say something about Larry Burkhardt from the staff.  
21 He was very helpful in helping us to prepare for this  
22 meeting. Thank you.

23 CHAIRMAN APOSTOLAKIS: Okay. The last  
24 part of the day and a half is to go around the table  
25 and you gentlemen will tell me what you think about

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1 AP1000. Shall we start with Jack?

2 MEMBER SIEBER: Well, as far as I'm  
3 concerned, I thought this for me was a pretty good  
4 learning experience because I'm not a PRA expert so  
5 the documentation was put together very well that I  
6 could understand it.

7 It seems to me from what I do know that  
8 the techniques and the calculations that you did are  
9 pretty straight forward and pretty standard. There  
10 were no surprises or places where I would feel  
11 inclined to scratch my head and doubt the information  
12 you put forth.

13 On that basis, I think the PRA document  
14 was well prepared and relatively easy to understand  
15 and your presentations were good. I don't have any  
16 negative comments at this time.

17 CHAIRMAN APOSTOLAKIS: Thank you. Bill.

18 MEMBER SHACK: Superb presentation. I  
19 found it very helpful. Reading through a PRA is kind  
20 of a painful thing. I thought the presentations were  
21 very well prepared. I feel pretty good about AP1000.

22 CHAIRMAN APOSTOLAKIS: So it's not just  
23 the presentation. It's the content as well.

24 MEMBER SHACK: Yes.

25 CHAIRMAN APOSTOLAKIS: It feels good.

1 MEMBER SHACK: It feels good. Warm  
2 feeling.

3 CHAIRMAN APOSTOLAKIS: Vic.

4 MEMBER RANSOM: It was a very good  
5 presentation and learning experience for me. The only  
6 thing I found a little bit surprising, I guess, were  
7 your comments in the end where it seemed like an awful  
8 lot of work had gone into this rather complex accident  
9 type situation with many things that I think the  
10 thermal hydraulics committee would obviously like to  
11 look into, I guess, or should.

12 On the other hand, if it has very little  
13 consequence, I'm wondering why did so much effort go  
14 into that and not more into the higher consequence  
15 things, I guess. It was a good learning experience.

16 CHAIRMAN APOSTOLAKIS: Remember that when  
17 we discuss philosophical operations in depth. Are you  
18 finished?

19 MEMBER RANSOM: Yes.

20 CHAIRMAN APOSTOLAKIS: Okay. Graham?

21 MEMBER LEITCH: Well, like my colleagues,  
22 I found the presentations very helpful. I thought  
23 they were well done. I think the staff has identified  
24 a number of appropriate issues that are still  
25 undetermined or are being worked on at the moment.

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1 I think there are a number of issues there  
2 that we need to hear the resolution of those issues,  
3 and obviously we will. I think that as we went  
4 through the presentations and then I heard the staff  
5 comment indicate where they still had some questions,  
6 I thought it was largely in line with the issues that  
7 I had in mind as well. I think they have identified  
8 the right issues and we just need to work our way  
9 through the resolution of this.

10 CHAIRMAN APOSTOLAKIS: Tom?

11 MEMBER KRESS: Well, I, too, though we had  
12 a very good PRA and a good presentation. I was a  
13 little bit shaken, like you were, about the state of  
14 the uncertainties but I don't think it matters very  
15 much.

16 The only areas where I still want to  
17 convince myself a little bit on are the squib valve  
18 reliability. I'm looking forward, like Steve is, to  
19 seeing the database that backs that up.

20 I still wasn't quite convinced mainly  
21 because I didn't have time to digest it all on the in-  
22 vessel retention and whether or not we found the worst  
23 configuration or the most problem configuration and  
24 whether or not it would fail the vessel.

25 Then I haven't -- we didn't see much

1 detail on the fuel-coolant interaction ex-vessel that  
2 we were all told is the same energetics as the AP600.  
3 I've forgotten what the AP600 energetics were and what  
4 they were based on so I've got to go back to the old  
5 ROAM and see what they did there.

6 Assuming that was acceptable then, it's  
7 probably acceptable now and they have a bigger,  
8 stronger containment here. It probably doesn't affect  
9 anything in the sense of the PRA. Staff, I think,  
10 appears to have asked the right questions and I'm  
11 anxious to see what kind of responses we get from  
12 them. All in all I don't see any show stoppers. I  
13 think it looks pretty good.

14 CHAIRMAN APOSTOLAKIS: Let me ask you  
15 gentlemen, you heard that the core damage frequency is  
16 what, 2. --

17 MEMBER KRESS: 4 times 10 to the -7.

18 CHAIRMAN APOSTOLAKIS: 4 times 10 to the -  
19 7. 2.4 events.

20 MEMBER SHACK: Internal events.

21 CHAIRMAN APOSTOLAKIS: Internal events  
22 every 10 million reactor years. Your gut feeling.  
23 How high do you think it could be given all the  
24 uncertainties that we have? They say it's a factor of  
25 6.

1 MEMBER KRESS: I think it could be as much  
2 as 2 orders of magnitude

3 CHAIRMAN APOSTOLAKIS: So that would make  
4 it 2.--

5 MEMBER KRESS: The question what's the  
6 probability of it being --

7 CHAIRMAN APOSTOLAKIS: Right. So the 95th  
8 percentile would be still on the order of 10 to the -5  
9 which is pretty.

10 MEMBER KRESS: Which is all right.

11 CHAIRMAN APOSTOLAKIS: Anybody else?

12 MEMBER SHACK: I don't see it from  
13 uncertainties, George. The nagging fear is that  
14 you've missed something. It's the completeness  
15 argument. I think you could analyze uncertainties  
16 until hell froze over.

17 CHAIRMAN APOSTOLAKIS: No.

18 MEMBER KRESS: I'm basing my 2 orders of  
19 magnitude on sort of the NUREG-1150 thinking which is  
20 supposed to incorporate that kind of thought.

21 MEMBER SHACK: Well, I don't know how to  
22 incorporate any completeness as an uncertainty.

23 CHAIRMAN APOSTOLAKIS: From the overall  
24 quality of what you heard and the review that the  
25 staff is doing, surely you don't think they missed

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1 something that has a probability of 1.

2 MEMBER SHACK: No. 10 to the -8, that's  
3 getting pretty tough.

4 CHAIRMAN APOSTOLAKIS: Do you think the  
5 contributor will be found six years from now that it  
6 would be 10 to the -3?

7 MEMBER SHACK: No.

8 CHAIRMAN APOSTOLAKIS: That's what I'm  
9 saying. You agree then with Tom?

10 MEMBER KRESS: When I start putting  
11 uncertainties on I talk about things like --

12 CHAIRMAN APOSTOLAKIS: I include  
13 incompleteness.

14 MEMBER KRESS: Yeah, I do, too.

15 CHAIRMAN APOSTOLAKIS: I include  
16 incompleteness. I am not like God.

17 MEMBER KRESS: If you didn't have  
18 incompleteness in there, you would only get an order  
19 of magnitude higher.

20 MEMBER SHACK: But I don't know what you  
21 do with incompleteness.

22 CHAIRMAN APOSTOLAKIS: Yeah, but you do  
23 know that it's not 1. You do, I think, believe that  
24 it's not 10 to the -4.

25 MEMBER SHACK: That's engineering

1 judgment, George.

2 CHAIRMAN APOSTOLAKIS: What else could you  
3 give me?

4 MEMBER SHACK: When it comes to things  
5 like the large break LOCA frequency, those numbers to  
6 me are probably conservative for pipe breaks. It's  
7 this notion is there some other way I can get a large  
8 break LOCA that I haven't thought about.

9 CHAIRMAN APOSTOLAKIS: But even that is  
10 not so unknown.

11 MEMBER SHACK: No. If I raise it by an  
12 order of magnitude, you know, it would still look  
13 pretty good.

14 MEMBER SIEBER: There's only so many  
15 things you can break.

16 CHAIRMAN APOSTOLAKIS: Sorry?

17 MEMBER SIEBER: There's only so many  
18 things you can break.

19 CHAIRMAN APOSTOLAKIS: Or open.

20 MEMBER SIEBER: Or open.

21 CHAIRMAN APOSTOLAKIS: So it seems to me  
22 that we have a consensus here that this is a very good  
23 piece of work.

24 MEMBER KRESS: It looks pretty good to me.

25 MEMBER SHACK: The other one is the plant

1 protection system. You know, those numbers.

2 CHAIRMAN APOSTOLAKIS: But, again, you  
3 know, when you find yourself in situations like that,  
4 start with extreme numbers. Is it too high? No, I  
5 don't believe it. Then you start working down and  
6 then pretty soon you have some fairly good idea.

7 I mean, you cannot say it's 6 times 10 to  
8 the -5 but some range. I believe most people here at  
9 the table, if not all, believe even if you look at the  
10 high-pressure the level would be below the goal.

11 MEMBER SHACK: I'm still glad to have a  
12 containment.

13 CHAIRMAN APOSTOLAKIS: I don't know why.  
14 Then those low numbers will go up in the name of  
15 defense-in-depth. But then we are not reviewing the  
16 errors of commission because we have never seen those.  
17 Right? We've seen many challenges to the containment  
18 but never errors of commission.

19 MEMBER RANSOM: One added question, I  
20 guess, would be is there any thought about considering  
21 terrorist-type acts and including that in a PRA?

22 CHAIRMAN APOSTOLAKIS: Not in the  
23 certification process. Don't look at me like that.

24 MEMBER RANSOM: It seems to me that would  
25 be an event that might be more likely than many of the

1 things we have heard.

2 MR. ROSENTHAL: This is Jack Rosenthal,  
3 Safety Margins and Systems Analysis Branch in  
4 Research. This is an open meeting and I don't think  
5 that is the forum to discuss it, but we could discuss  
6 issues in some other forum.

7 CHAIRMAN APOSTOLAKIS: That's your answer.  
8 Anything else? Well, thank you very much. I would  
9 like to thank you again and the staff for taking the  
10 trouble to come here and prepare these presentations.  
11 Yes, I would add my congratulations also to you. It  
12 was a great presentation. Especially when Selim says  
13 that we can talk about it philosophically forever and  
14 never reach a conclusion. Thank you all. This  
15 meeting is adjourned.

16 (Whereupon, at 2:20 p.m. the meeting was  
17 adjourned.)

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**CERTIFICATE**

This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission in the matter of:

Name of Proceeding: Advisory Committee on  
Reactor Safeguards  
Subcommittee on Reliability  
and Probability Risk  
Assessment

Docket Number: n/a

Location: Rockville, MD

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission taken by me and, thereafter reduced to typewriting by me or under the direction of the court reporting company, and that the transcript is a true and accurate record of the foregoing proceedings.



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Matt Needham  
Official Reporter  
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