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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

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

A-G-E-N-D-A

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 stated in the Federal Register notice.

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

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

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

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

I just wanted to say that the Level 2 PRA and the phenomenological studies have been performed by collaborative effort with Westinghouse. Also with members of FORDUM which is a Finish utility that has worked in this area.

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

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

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

MR. CORLETTI: Yes, sir.

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

MR. CORLETTI: In the PRA?

MEMBER SIEBER: Yeah.

MR. CORLETTI: Chapter 35 -- 34.

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

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

MEMBER SIEBER: Scroll.

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

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

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

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

This is the containment of entry structure. You can see it's a small containment of entry. It's got 23 paths on it. We quantify one of these for each of the accident classes using fault tree linking techniques for the system nodes. There are a few phenomenological notes on there as well that we will cover.

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

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

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

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

MEMBER KRESS: Pretty low frequency.

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

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

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

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

MR. SCOBEL: Yes.

MEMBER LEITCH: Okay.

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

MR. SCOBEL: Yes.

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

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

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

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

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

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

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

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

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

MR. SCOBEL: Exactly.

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

MR. SCOBEL: The phenomenology?

MEMBER ROSEN: Yeah. What exactly happens?

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

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

MR. SCOBEL: Right. Exactly.

MEMBER ROSEN: We can talk about it anyway.

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

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

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

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

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

Because they are also very thin and they have high hoop stresses, what we see is that it becomes kind of a 50/50 probability which component will fail first if you look at this on a current plant.

MEMBER KRESS: And we thought this out.

MR. SCOBEL: I'm sure you have.

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

MEMBER SHACK: If you had a loop.

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

MR. SCOBEL: About the hot leg?

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

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

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

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

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

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

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

MEMBER KRESS: I agree that is a conservative assumption. I guess we have to hone in on questioning it later to look at more detail on your assumption that it's depressurized and flooding melt through. That's the first phase in this. There's the place where there are some questions but that is a good assumption.

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

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

MR. SCOBEL: Just for fun.

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

MR. SCOBEL: Yes.

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

MR. SCOBEL: Okay.

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

MR. SCOBEL: Yes.

MEMBER KRESS: For the same reason.

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

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

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

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

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

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

MEMBER KRESS: Yes.

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

MR. SCOBEL: Actually, in the accident sequence we think about how we model that in the MAAP code. Actually, it would fail the vessel because you don't depressurize that much from the -- you would have to go on -- in the accident sequence you would have to go on and then probably melt through a hot leg and model that. Then you would depressurize. That would be your depressurization mechanism later on in the accident sequence.

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

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

MEMBER KRESS: It doesn't matter.

MR. SCOBEL: It doesn't matter.

MEMBER KRESS: If you have a high source term.

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

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

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

MR. SCOBEL: Design leak rate from the

containment. We calculate --

MEMBER KRESS: Adjust it for the pressure.

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

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

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

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

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

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

The accident classes labeled 1 are the high-pressure accident classes. They include core damage following a transient such as loss of feed water or turbine trip or something like that. Core damage from a small LOCA or an RCS leak with the passive RHR heat exchanger working.

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

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

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

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

3C is core damage following a vessel rupture which occurs below the elevation of the core in the vessel so you can't recover the core until you flood up the containment all the way past the break.

MEMBER KRESS: That must be a low frequency.

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

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

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

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

CHAIRMAN APOSTOLAKIS: Regarding what?

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

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

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

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

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

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

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

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

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

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

CHAIRMAN APOSTOLAKIS: Through the accumulator.

MR. SCOBEL: No, from gravity injection.

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

MR. SCOBEL: Gravity injection is from the IRWST.

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

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

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

MR. SCOBEL: Selim.

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

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

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

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

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

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

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

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

MR. SCOBEL: Yes.

MR. CORLETTI: So we require the CMTs to

drain to actuate ADS.

MEMBER ROSEN: To automatically actuate.

MR. CORLETTI: Yes.

MEMBER ROSEN: You can always actuate ADS manually.

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

MR. SCOBEL: Yes.

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

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

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

Containment isolation failure which is a release that goes through the containment so you get some attenuation of fission products but then there is a release of fission products to the environment through what we consider to be an open HVAC line which is an 18-inch diameter hole in the containment. Early containment --

MEMBER ROSEN: Is that the biggest line?

MR. SCOBEL: That is the biggest line.

MEMBER ROSEN: In this plant?

MR. SCOBEL: Yes, it is.

MEMBER ROSEN: 18-inch.

MR. SCOBEL: The 18-inch.

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

MEMBER ROSEN: It's the biggest ventilation one.

MR. CUMMINS: Yes.

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

Intermediate containment failure which is a containment failure which is a containment failure that occurs after the high energetic core relocation period of the accident when you are out in time and the containment becomes well mixed and you fail the containment but it's prior to 24 hours which is kind of a magic number, one day after the accident.

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

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

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

Especially considering that we lump all of the vessel failures into early containment failure. A lot of your severe challenges that would come associated with long-term ex-vessel phenomena such as core concrete interaction are already accounted for in early containment failure. Also, late containment failure 10 to the 13th, 14th, 15th even. We don't have a lot of frequency of these CFL and CFI.

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

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

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

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

3A. These are the ATWS accident sequences and they have a very poor containment performance. In fact, as you will see later, these are dominant core damage sequence related to ATWS, or large release sequences. Also most of our large release is also tied up in steam generator tube rupture initiated accidents.

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

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

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

MR. SCOBEL: Yes.

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

MR. SCOBEL: Well, yes, except that our intermediate and late failures are so small that our large release frequency and our large early release frequency are the same number. That's why we just call it a large release frequency. There's not much intermediate and late. Our CCFP for this plant is 8 percent which is one minus this number here.

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

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

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

MEMBER KRESS: For that.

CHAIRMAN APOSTOLAKIS: For that.

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

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

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

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

8 percent.

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

MR. SCOBEL: Yes.

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

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

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

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

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

MR. SCOBEL: These values?

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

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

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

MEMBER KRESS: For different bins of

frequency, though.

CHAIRMAN APOSTOLAKIS: Yeah.

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

CHAIRMAN APOSTOLAKIS: You mean satisfy?

MEMBER KRESS: Satisfy.

CHAIRMAN APOSTOLAKIS: It does.

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

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

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

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

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

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

CHAIRMAN APOSTOLAKIS: Which is?

MR. SCOBEL: Bypass is here.

CHAIRMAN APOSTOLAKIS: BP.

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

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

MR. SCOBEL: From the consequence point of view.

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

MR. SCOBEL: Yes.

CHAIRMAN APOSTOLAKIS: This is almost the whole thing.

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

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

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

CHAIRMAN APOSTOLAKIS: 6 and 3A.

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

MEMBER ROSEN: 3A is inducted?

MR. SCOBEL: 3A is ATWS.

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

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

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

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

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

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

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

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

MEMBER SIEBER: Nice try.

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

MR. SCOBEL: Yes. In fact --

CHAIRMAN APOSTOLAKIS: Where do I see

that?

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

CHAIRMAN APOSTOLAKIS: And these are the most frequent?

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

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

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

CHAIRMAN APOSTOLAKIS: Okay.

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

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

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

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

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

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

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

MR. SCOBEL: Just a little taller.

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

You're just calculating a large early release which is really a large -- is when you go to failed containment early in line so that this large early release would compare to the NRC acceptance criteria if they had one.

MR. SCOBEL: Yes.

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

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

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

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

MEMBER KRESS: Without MAAP?

MR. SCOBEL: With MAAP.

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

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

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

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

MEMBER KRESS: You don't have a site.

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

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

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

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

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

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

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

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

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

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

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

MR. SCOBEL: Yes.

MR. SNODDERLY: So just to keep it in

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

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

MR. SNODDERLY: Great.

MR. SCOBEL: And I'm almost done.

MR. SNODDERLY: Okay. Great.

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

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

Finally, we set the vessel failure probability to 1. This is with regards to -- for our vessel failure probability we looked at you could fail the vessel high up on the vessel and not release debris of the containment with our assumption that if you release debris of the containment, you get an early containment failure. We weren't getting all early containment failures in 3C. In this we set the probability of 3C vessel failure to 1. We came up with 11.8 percent for the CCFP.

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

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

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

Cavity flooding has a strong impact on

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

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

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

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

That's a conservative assumption. We get into a realm where we have some probability of containment failure based on the containment furgility curve. It's not real high unless you consider -- I'm going to cover this under the phenomena.

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

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

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

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

MR. SCOBEL: That is the core damage frequency.

MEMBER SHACK: Then you assume it's 1.

MR. SCOBEL: Yes.

MEMBER SHACK: How about that.

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

MR. SCOBEL: No, they are.

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

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

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

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

MR. CUMMINS: This is Ed Cummins. Maybe

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

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

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

MR. CUMMINS: Yes.

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

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

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

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

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

MEMBER ROSEN: What's the EDE stand for?

MR. SCOBEL: Effective dose equivalent. From this plot I guess the goal is right about here if we were to go above this line here.

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

MR. SCOBEL: Yes.

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

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

--

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

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

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

MEMBER KRESS: That's a frequency consequence.

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

MEMBER KRESS: Yeah. It tells me a lot.

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

MEMBER KRESS: Thank you.

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

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

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

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

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

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

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

MR. SCOBEL: Well, 25 rem is --

CHAIRMAN APOSTOLAKIS: Oh.

MR. SCOBEL: This is the core damage.

CHAIRMAN APOSTOLAKIS: It can't be up there.

MR. SCOBEL: This is the core damage frequency.

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

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

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

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

MEMBER ROSEN: And so your standard

doesn't include gamma dose?

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

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

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

MR. SCOBEL: I believe so, yes.

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

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

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

CHAIRMAN APOSTOLAKIS: What bothers me the age of the earth's crust is 3 times 10 to the 9th years. If you've had one event or one release, you will get a frequency of 3 times 10 to the -10.

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

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

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

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

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

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

MR. SCOBEL: What's next?

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

CHAIRMAN APOSTOLAKIS: Very good.

MR. SANCAKTAR: My objective here was to

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

MEMBER ROSEN: Do you have a microphone on?

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

MR. SANCAKTAR: Is that better?

CHAIRMAN APOSTOLAKIS: Put it on your tie.

MR. SANCAKTAR: Okay.

CHAIRMAN APOSTOLAKIS: High.

MR. SANCAKTAR: Okay. How's this?

CHAIRMAN APOSTOLAKIS: How you're wired.

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

MEMBER ROSEN: Yes.

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

CHAIRMAN APOSTOLAKIS: Don't do it then.

MR. SANCAKTAR: This slide was shown yesterday also. It's the same slide I showed yesterday. This just kind of shows the relation between AP600 and AP1000. It compares the numerical results and also shows the areas where analyses were performed.

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

CHAIRMAN APOSTOLAKIS: With significant margin?

MR. SANCAKTAR: With significant margin.

CHAIRMAN APOSTOLAKIS: How do you know that?

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

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

MR. SANCAKTAR: Yeah.

CHAIRMAN APOSTOLAKIS: Something that has never been built and you are claiming 10 to the -7 core damage frequency. You can only be uncertain by a factor of 6?

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

CHAIRMAN APOSTOLAKIS: Converted to that.

MR. SANCAKTAR: Converted.

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

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

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

Then what I'm doing is I'm looking back at the LWR and I'm seeing the numbers going all over the place as we learn more with more experience. I think it's an under estimate. I'm not saying that the changes are based on conclusions but I think saying that you're meeting the goals with significant margin is pushing it a little bit. You just don't know. I don't know. You may be right but I don't know.

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

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

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

MEMBER KRESS: According to what?

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Two difference departments of Sandia Laboratories sent us letters back in writing. They gave us their data, number of hours, number of failures. From that we obtained two different values, two more values. We have one number that the URD gave us. We didn't throw it away but it is kind of suspicious.

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

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

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

MR. SANCAKTAR: Right.

MEMBER KRESS: Average.

MR. SANCAKTAR: We have three numbers now. We don't know which one is right and which one is wrong. We don't want to pass judgement on it so we checked with three experts. They gave us three different numbers. We too a geometric average of the three numbers and we came up with a number 5.8 times 10 to the -4. We don't anything else. We don't have our own tests. We don't have any magic numbers. We just looked around for --

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

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

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

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

MR. SANCAKTAR: Okay.

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

MR. SANCAKTAR: Certainly.

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

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

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

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

MEMBER SHACK: This is a valve that sits

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

MEMBER ROSEN: That's what worries me.

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

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

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

MEMBER ROSEN: I know. I know, but at least phenomenlogically --

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

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

MEMBER ROSEN: I am a hands-on plant kind of guy. I like to see things that are supposed to work work. And then I can get some familiarity with how they work. And then when I'm comfortable that they work, I'm comfortable. Right now we're just talking about data and analysis, and that's interesting but the closer you can get to the ideal, I know you can never achieve it but I want to hear more about that.

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

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

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

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

MR. SANCAKTAR: Yes.

MEMBER ROSEN: Are you done Selim?

MR. SANCAKTAR: Yeah, I'm done.

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

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

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

MEMBER KRESS: You want to take a break now?

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

(Whereupon, off the record.)

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

MR. SCOBEL: Okay. I am going to talk about what we've done for in-vessel retention for the AP1000. Just a little run-through for anybody who doesn't have a strong background in in-vessel retention, the phenomena that we're talking about is maintaining molten-core debris in the lower head of the reactor vessel by externally cooling the outer surface of the reactor vessel with water.

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

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

MR. SCOBEL: Yes.

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

MR. SCOBEL: Yes.

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

MR. SCOBEL: Based on the melt relocation phenomena, which I'll get into a little later, what you end up with is oxide debris filling up the lower plenum and contacting the metal debris from the bottom allowing the metal debris to then melt on top of the oxide debris with a crust in between.

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

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

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

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

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

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

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

This is a cartoon of reactor vessel

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

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

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

MEMBER SIEBER: Yeah, a float valve.

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

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

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

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

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

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

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

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

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

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

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

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

MEMBER ROSEN: So it pops them off.

MR. SCOBEL: Pops them off.

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

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

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

MEMBER SIEBER: Okay.

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

MR. SCOBEL: There are four of these.

MEMBER KRESS: Four of these?

MR. SCOBEL: Yes.

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

MR. SCOBEL: Yes.

MEMBER KRESS: Located 90 degrees apart.

MR. SCOBEL: Yes.

MEMBER ROSEN: Kind of like Rogers.

MEMBER KRESS: Has that configuration been tested somewhere?

MR. SCOBEL: Yes, it has actually.

MEMBER KRESS: ROSPLOT?

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

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

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

Also the steady state two-layer debris configuration presented the limiting challenge to the reactor vessel. I should say the credible limiting challenge to the reactor vessel which was a metal over oxide debris bed configuration in the lower plenum.

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

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

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

MEMBER KRESS: The heaters were put into the oxide?

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

MEMBER KRESS: Hot debris in the first place?

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

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

MR. SCOBEL: Yes.

MEMBER ROSEN: -- what the condition is?

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

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

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

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

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

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

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

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

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

Also to demonstrate that the correlations that we're using for the heat transfer if they continue to scale properly for AP1000 or if we've exceeded the scaling of the testing that we had already done.

MEMBER KRESS: Is the vessel diameter about the same?

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

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

MR. SCOBEL: Say that again, please?

MEMBER KRESS: Did you repeat the ROAM?

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

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

The ULPU Configuration 4 was still set up with the AP600 entrance and exit losses but we actually did not consider this to be a major limitation. We didn't think that was a limiting factor in the test.

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

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

MEMBER KRESS: Yeah, I know what you mean.

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

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

MR. SCOBEL: Probably not because it's not an acronym.

MEMBER ROSEN: Oh.

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

MEMBER ROSEN: Cruel.

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

MEMBER BONACA: She doesn't look that good.

MR. SCOBEL: Sorry?

MEMBER BONACA: She doesn't look that good.

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

MEMBER KRESS: When you talk about power

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

MR. SCOBEL: Yes.

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

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

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

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

MR. SCOBEL: Yes.

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

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

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

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

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

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

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

MEMBER KRESS: In order to get the void fraction.

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

MR. SCOBEL: Right. Exactly.

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

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

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

MEMBER KRESS: That has an affect on the velocity.

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

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

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

MEMBER RANSOM: Are those critical heat flux values?

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

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

MR. SCOBEL: Actually, it is. Then we had some conclusions from ULPU Configuration 4. We submitted the test report to the NRC. In fact, this is the number. CHF can be increased significantly to accommodate AP1000 but we have to channel the flow around the lower head and we have to do it with a high water level.

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

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

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

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

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

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

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

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

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

MR. SCOBEL: This is nuclear boiling.

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

MR. SCOBEL: That's correct.

MEMBER ROSEN: Otherwise it would drop off dramatically.

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

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

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

MR. SCOBEL: This was step one.

MEMBER KRESS: I'm sorry.

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

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

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

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

MEMBER ROSEN: Normally oxidized just because the plant runs.

MR. SCOBEL: Yes.

MEMBER ROSEN: Do you have to preoxidize?

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

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

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

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

MR. SCOBEL: Yes.

MEMBER KRESS: What do you call thermal failure?

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

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

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

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

MR. SCOBEL: Because it melts through.

MEMBER KRESS: It melts through. Okay.

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

MR. SCOBEL: Exactly.

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

MR. SCOBEL: Yes.

MEMBER KRESS: Because the metal is thin.

MR. SCOBEL: Yes.

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

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

MR. SCOBEL: Yes. For the structural failure we wanted to confirm at the higher power level that we were still okay and considering abounding heat flux of 2000 -- the heat fluxes that we are expecting from AP1000 are actually about 1,400 or 1,500 kilowatts per square meter so this is a heat flux.

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

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

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

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

MEMBER KRESS: MAAP 4 results?

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

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

MR. SCOBEL: No. Actually, it was done

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

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

MEMBER KRESS: This was part of the ROAM process?

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

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

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

You have a sideward failure through the reflector into the dead-ended region which would then allow the debris to contact the core barrel. The core barrel would fail and the debris would relocate into the lower head.

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

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

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

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

When you got the initial relocation into the lower head, you would have this oxide pull that would melt through the reflector and then the core barrel and then pour down into the lower head and contact the lower support plate from below. It all occurred in kind of one fell swoop and filled up and contacted the lower support plate.

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

This is a picture of the core shroud which is not really compared to the reflector but the shroud part itself is seven-eight's of an inch thick around the core and it has the support rings on the outside.

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

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

MEMBER KRESS: All that is steel?

MR. SCOBEL: It's all stainless steel. So in modeling this core relocation, the first thing we needed was an accident sequence, by definition a successful IVR fully depressurized. We want to look at the earliest core uncovery core melt progression because of decay heat being higher so that's conservative.

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

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

Now, this model had its limitations in that it actually couldn't model the melting and relocation of the core once it heated up to a certain level. We also have --

MEMBER KRESS: Finite difference models are usually fixed geometry.

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

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

MEMBER KRESS: Radiation?

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

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

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

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

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

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

MEMBER ROSEN: Top of the oxide?

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

MEMBER SIEBER: I would have sort of

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

MR. SCOBEL: In the peripheral fuel assemblies?

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

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

MEMBER SIEBER: That's true.

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

MEMBER SIEBER: Still standing.

MR. SCOBEL: You see, this is --

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

MR. SCOBEL: It's also a conservative assumption. I'm sorry. It's a conservative assumption, too. There's like so much stuff to this that keeping track of it is difficult. But it's conservative also to assume that the peripheral fuel assemblies are standing because it significantly limits the mass associated with this initial relocation which, as we continue to talk about the progression, it sounds funny that we want more melted fuel but we do. What we want to do is we want to contact the lower support plate like we did in AP600 to melt the metal debris on top of the oxide debris.

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

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

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

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

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

MR. SCOBEL: The other really likely

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

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

MR. SCOBEL: Actually --

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

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

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

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

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

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

MR. SCOBEL: Yes.

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

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

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

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

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

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

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

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

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

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

MEMBER KRESS: So you've got --

MR. SCOBEL: That's conservatively high.

MEMBER KRESS: You've got competition

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

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

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

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

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

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

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

In the end what we came up with, since I have to go fast, we have like an early timing and a duration for relocation. This is for our modeling of the subsequent relocation of the debris. We model each of the regions and we keep track of how much heat is in each one and how much mass based on our conservative calculations of how much initially relocated.

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

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

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

MR. SCOBEL: Design basis accidents don't have melting fuel.

MEMBER KRESS: This is all for the PRA?

MR. SCOBEL: This is all for the PRA. This is all for IBR specifically.

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

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

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

MR. SCOBEL: Yes.

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

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

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

MR. SCOBEL: Down here?

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

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

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

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

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

MR. SCOBEL: Yes.

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

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

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

MR. SCOBEL: That's taken --

MEMBER KRESS: It's the heat flux and the temperature that you get on the bottom side that determines whether you're melting it.

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

MEMBER KRESS: Show me where the documentation is.

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

MEMBER KRESS: Of the oxide. Right.

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

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

MR. SCOBEL: Yes. So you --

MEMBER KRESS: You get the heat flux.

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

MEMBER KRESS: And that fixes the metal temperature.

MR. SCOBEL: And that fixes -- exactly.

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

MR. SCOBEL: Yes, sir. That's exactly!the model we have.

MEMBER KRESS: Ok`y.

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

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

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

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

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

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

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

that they contradict our position because for our conditions --

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

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

MEMBER KRESS: Material interactions.

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

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

MR. SCOBEL: Not necessarily. No, actually.

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

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

MEMBER KRESS: Are they exothermic?

MR. SCOBEL: They are actually oxidation

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

MEMBER KRESS: Almost neutral.

MR. SCOBEL: Yeah.

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

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

MR. PALLA: I think yes.

MR. SCOBEL: Bob Palla thinks yes.

MEMBER RANSOM: And the data is open?

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

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

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

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

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

MEMBER RANSOM: Good.

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

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

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

MR. SCOBEL: Actually have a metal layer?

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

MR. SCOBEL: You do. Even in RASPLAV and MASCA they saw the separation of the layers. Those would be the tests where we would --

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

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

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

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

In addition, I should mention addition of boron carbide to the melt in addition to iron that accentuates this whole melt separation where you have larger amount of metallic melt relocated to the bottom.

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

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

MEMBER KRESS: Then it just helps you.

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

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

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

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

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

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

MR. SCOBEL: Yeah.

MEMBER KRESS: That would be going too far.

MR. SCOBEL: Yes.

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

MR. SCOBEL: MELCOR.

MEMBER RANSOM: MELCOR.

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

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

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

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

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

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

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

MEMBER ROSEN: Could you talk into the microphone?

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

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

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

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

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

MR. SCOBEL: I don't know if this answers your question but if I were to model this in the MAAP code with AP1000 I don't fail the vessel. MAAP has lower head cooling models.

MEMBER KRESS: Oh, MAAP does.

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

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

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

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

metal over oxide debris pool configuration.
We use the DOE methodology that Theo developed. We are using the new critical heat flux from ULPU Configuration 4.

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

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

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

The probability distributions of the heat loads look like this out here at the maximum. You can see we are about the same place for that bounding calculation that I presented earlier which is about 70 percent.

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

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

That's the end of the IVR presentation.

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

MR. SCOBEL: Yes.

MEMBER ROSEN: Tom asked a few questions about that. I guess what I'm struggling with is trying to get the confidence that the sequence is as you suggest. Did you do any similar calculations for other model or sequences of the melt progression and assure yourselves that this is the most severe one?

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

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

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

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

I don't know if there's a map there or something but they have some conditions that are actually similar to what I would say would be a bounding condition for AP1000. The heat flux that they are getting at the bottom of the vessel is uniform over the entire bottom metal layer. It's like 4 megawatts.

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

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

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

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

You have a total thickness of the metal

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

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

MR. SCOBEL: You mean this temperature?

MEMBER KRESS: Is the bottom layer a solid?

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

MEMBER KRESS: Just not circulating.

MR. SCOBEL: Yes.

MEMBER KRESS: Okay.

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

PARTICIPANT: Two dimensional.

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

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

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

MEMBER KRESS: Just a DTSE ratio there.

MR. SCOBEL: Sorry?

MEMBER KRESS: Take the total inventory and DTSE ratio.

MR. SCOBEL: Yes. Yes. I'm assuming that it's 100 percent of that decay heat so it's not just the metals. The initial masses of the metal involved in the reaction is 3,000 kilograms of stainless steel because that is actually what's down there already, and 7,000 kilograms of zirconium because that's what I can calculate could potentially be molten at the time when you are relocating oxide.

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

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

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

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

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

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

MEMBER RANSOM: In terms of this energy

source. Right.

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

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

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

MEMBER RANSOM: Does not?

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

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

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

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

DOE report.

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

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

MEMBER KRESS: You're reiterating on those.

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

MEMBER KRESS: I see.

MEMBER RANSOM: What is the internal heat generation term?

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

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

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

MEMBER RANSOM: No. I was just -- I don't know. It would take me some time to look into it to see if you included conduction through the conduction layer as well as internal heat generation in the layer.

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

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

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

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

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

MEMBER KRESS: Those wouldn't have any

heat in them.

MR. SCOBEL: Sorry?

MEMBER KRESS: No heat in them.

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

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

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

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

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

Why don't we try to spend 15 minutes on the ex-vessel phenomena to help the committee to understand that you have done some analyses to address the fact that if, indeed, in fact the melt would be to go ex-vessel, you've done some studies so I think it's important for them to hear about that.

MEMBER KRESS: Is this FCI?

PARTICIPANT: FCI, high-pressure melt, CCI.

MEMBER KRESS: Okay. NCCI.

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

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

We don't expect a massive bottom failure to relocate the entire core at one time into the lower head. The sideward pathway gives you the largest mass flow rate at one time. If you were to assume that it came out through the holes in the reflector, it's a very limited flow pathway. We have a similar debris relocation pathway with similar debris flowrate into the same geometry.

MEMBER KRESS: But you have a higher fraction.

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

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

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

Mike, you were head of that, right?

It was all based on testing program that was done specifically for that AP600 ROAM. That's my politician answer to the question. I don't know what the conversion factor was. We rely on the AP600 results. Since we had so much margin to failure, we have a similar type relocation that is no different for AP1000 for in-vessel steam explosion.

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

MEMBER KRESS: Does your hydrogen source stem from MAAP?

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

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

MR. SCOBEL: Yes.

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

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

There are vents all the way around the

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

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

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

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

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

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

these vents, then these vents don't open.

MEMBER KRESS: And you have ignitors somewhere in there?

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

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

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

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

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

If, in fact, you have stage 4 ADS available, you will be releasing hydrogen away from the containment wall anyway. This will be where it's going. It's only in the event that you don't have stage 4 ADS open that you have releases through the IRWST into the containment so it's not a dominant sequence but it's a consideration for defense in depth.

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

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

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

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

The hinged vessel failure of the lower

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

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

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

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

MEMBER KRESS: Same faction of metal.

MR. SCOBEL: Yes.

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

MR. SCOBEL: Yes.

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

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

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

MR. SCOBEL: We're extending that conclusion to AP1000, yes.

MEMBER SHACK: Is it better or worse because you have a higher design pressure in there in the AP1000? Right?

MR. SCOBEL: We didn't take credit for that.

MEMBER KRESS: Actually, you might be better off because you expect the same sort of energetics, the same mass material. It's the same metal and you get the same sort of energetics. You've got more water. If you've got too much water, it actually helps. You're probably better off with AP1000 then you were in AP600. A bigger containment volume, higher pressure.

MEMBER SHACK: Bigger is always better. Right?

MEMBER ROSEN: Let's pick it up.

MR. SCOBEL: Okay. The core concrete interaction. This is another ex-vessel phenomena prevented by in-vessel retention. We looked at two vessel failure modes, hinged failure and a localized failure. The hinged failure tends to spread the debris.

The localized failure tends to pile the debris up under the reactor vessel and not spread. We looked at two concrete types, limestone and basaltic, so that in the event we decide we want to use either one, we're not limited by the analysis. Our success criteria was the basemat remained intact for 24 hours.

It was done with MAAP 4 and the minimum time to basemat failure in the analyses with all the different kinds of concrete was 2.8 days to melt through the basemat. In all of our cases the basemat melt through occurs before you over-pressurize the containment with noncomencable gasses.

MEMBER KRESS: You used MAAP 4 to consider retransfer to the water on top?

MR. SCOBEL: Yes, but we limited the amount of water on top like we would for our normal vessel failure case so it dried out pretty quickly actually.

That's another thing actually. To do this analysis we limited the amount of water that was available at the initial vessel failure. Under normal circumstances that water would actually recycle back to the cavity.

MEMBER KRESS: It would condense on the --

MR. SCOBEL: Yeah. It would condense on

the shell. We subverted that process so that it remained dry. This was a dry calculation.

MEMBER KRESS: Radiation off the top and down through the cavity.

MR. SCOBEL: Those were the things that you specifically wanted to see. Equivalent survivability, I believe, is my last slide. Are there any other severe accident issues that you would like to discuss as I would be happy to do so?

MEMBER ROSEN: Is this the end of your prepared remarks or how much more time do you need?

MR. SCOBEL: I'm done.

MEMBER ROSEN: Completely done. And Selim is going to come up now?

MR. SCOBEL: Selim is done now.

MEMBER ROSEN: So we're all done.

MR. SCOBEL: We're done and the only thing left at the end of the day would be talk about the next steps for future meetings.

MEMBER SHACK: Could you say a couple words about the dry PCS cooling?

MR. SCOBEL: Sure.

MEMBER SHACK: That's for all sequences we're talking?

MR. SCOBEL: Okay. Yes.

MEMBER SHACK: You've got the PCS cooling here so we'll buy that. It was the dry one that I was interested in.

MR. SCOBEL: Dry PCS cooling is sufficient to prevent containment failure for at least 24 hours -- it's actually more than that -- based on our success criteria which is the containment fergility curve. Under nominal conditions like nominal containment the temperature outside, we don't expect any failure probability at all.

Now, conservatively if you take ANS decay heat plus 2 sigma and an outside temperature of 115 degrees, we came up with a failure probability of two percent at 24 hours. In fact, we used that number conservatively in the PRA as our containment failure probability at 24 hours if you don't have PCS cooling.

That could have been -- we could have made it zero and then made that an uncertainty calculation but it really wouldn't have shown up that way either. It doesn't show up anywhere even with the 2 percent because PCS water reliability is so good and we didn't even credit all the capability of that system. It was just easier to just go the conservative route, take the hit on 2 percent.

MEMBER KRESS: This decay heat is all

going into steam. Right?

MR. SCOBEL: The decay heat is all going into steam. When we do these calculations we actually cool the core because that maximizes the heat load to the containment and gives you the earliest time for containment failure.

MEMBER KRESS: Heat transfer on the outside air duct, is that what's controlling the -- you've got condensation on the inside?

MR. SCOBEL: The end transfer on the outside is controlling because you don't have the evaporation. You just have the convective cooling of the flow through the PCS annulus. Failure is by over-pressurization. Anything else?

MEMBER ROSEN: No. I think unless the members have any further questions, I don't see any interest in that. Any further comments from any member of the audience?

If not, we have a session that begins at 1:15 this afternoon if I'm not mistaken with the staff taking over. NRC staff presentation begins at 1:15. I assume Westinghouse will stick around for that and we'll see you all back here then at 1:15.

(Whereupon, off the record for lunch to reconvene at 1:15 p.m.)

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

1:17 p.m.

MEMBER ROSEN: Output for the research report. Make sure you take it with you and do what you are supposed to do based on that. I have now fulfilled my obligation to Dr. Ford.

MEMBER SHACK: Let me just mention that if you have any editing comments, either send them to me or give me a marked up copy so I can include those when I'm doing the lowly-paid editor's job.

MEMBER ROSEN: Okay.

MEMBER SIEBER: Is this going to be sent to us by e-mail attachment or anything?

MEMBER ROSEN: I don't know. You would have to ask Peter.

MEMBER SIEBER: That would be great if we would and it's easier for you and me.

MEMBER ROSEN: Yeah, that's a good thought because I'm going to have to revise parts of this so if I had it electronically it would be easier.

MEMBER SIEBER: Yeah. It makes everything much simpler.

MEMBER SHACK: I think Peter is intending to do that.

MEMBER ROSEN: Okay. Let's get on with

the afternoon's entertainment. Mr. Palla.

MR. PALLA: Okay. Hi. I'm Bob Palla. I'm in the Probabilistic Safety Assessment Branch of NRR. We are responsible for reviewing both the Level 2 PRA. You heard about the Level 1 yesterday. I'm going to speak to the Level 2 and 3 portions of the PRA and the severe accident analyses that are part of the application in support of the PRA.

As background, the review in these areas is split between the Office of Nuclear Reactor Regulation and our Office of Research. We are reviewing the Level 2 and 3 PRAs within NRR but in the area of severe accidents we rely heavily on the Office of Research to perform the more in depth review of the specific underlying analyses of severe accidents and some of the reviews of the phenomenological analyses.

Richard Lee will present a brief discussion of the research activities as soon as I'm finished here. The sooner the better. You get to hear the real substantial information.

Our review objectives and approaches basically as Nick Saltos outlined it to you yesterday, we want to look at PRA in terms of is the quality sufficient to support the intended use. Does it sufficiently guide the insights regarding the safety of the design and what's important to the design.

We want to also focus on the similarities and the differences between AP600 and AP1000 for help. Basically to provide some efficiency in the review. We will be looking most closely at these areas of differences like the increased power levels and how that influences in-vessel retention, molten debris masses that could affect core concrete interaction and these kind of aspects of the model. We'll look at the impacts that they would have on the major results.

Now, what I've got on the remainder of this slide and on the next slide is in essence a high-level summary of the areas of concern that we addressed in the request for information that we transmitted to Westinghouse.

This presentation might have been a little more meaningful if it would have preceded the presentation by Jim Scobel because then you might pick up on those things that were presented that were specifically in the areas that we were asking for. I'll kind of point it out here just what the key areas are. Many of these areas you've already heard Jim explain analyses in part but then we'll answer our questions.

It's kind of a broad-sweeping issue that we had with the AP1000 submittal was that when it came to issues like hydrogen generation and mixing and the probability of distributions used within the Level 2 analysis. Thermal loads on the vessel for example, the in-vessel and ex-vessel fuel cooling interactions, as well as the fission product release fractions.

All of this information was in the AP vessels. We didn't receive AP1000 specific analyses on those issues. Rather, what Westinghouse approached in the initial supplemental was that the composition, the masses, the super heat that was calculated for AP600 is similar and similar enough to AP1000 that the results were bounding.

I guess in recognition of the power differences between the plants and the changes that were made with reactor vessel internals like the shroud replacing the reflector, and also some of the information in the AP1000 submittal was suggestive of the possibility that accident progression is quite a bit more drastic than AP1000 because of AP600.

For all of those reasons we were skeptical in accepting at face value without some kind of justification or analysis to support the statement that the various aspects of the analysis were directly applicable.

Jim explained much of this today. He presented AP1000 specific calculations in several of these areas. We expect that's largely going to be responsive to the kinds of issues that we were concerned about. We'll be looking for closely at that information.

MEMBER SHACK: The responses you have to the RAIs, or at least Westinghouse thinks they have answered these questions.

MR. PALLA: We have not had a feedback yet. We are still early in the process of looking through. We've given them a quick look. I think Richard may be able to speak a little bit more definitively. I think they are a little further along in their reviews.

In some regard, some of the areas that they are looking at are the same things that we're looking at. In-vessel retention we're kind of both looking at it, but we look to them to provide the real horsepower for the details.

For example, the RASPLAV and the MASCA test results, are they applicable or not. Are they prototypic. This is something that Research and Ali Behbahani is much more familiar with so we will be relying on them.

I don't want to prejudge something as being a resolved issue if I think it's closed, but then they upon further thought and reflection on it might think there are still some additional details there. I'm going to be kind of noncommittal to saying things are resolved. The state that are, at least in my mind, is that we are still looking at these things.

Applicability of AP600 results. We now have AP1000 specific calculations that we will be looking at so that hole has been plugged. In the area of external reactor vessel cooling, as Jim mentioned, the same logic as was used in AP600 has been used for AP1000.

Basically if the reactor cavity is successfully flooded with a different success criteria -- there's been a tweaking on the success criteria -- and if the RCS is fully depressurized, the debris stays in-vessel.

Now, we've looked at that for AP600 and we concluded in our review for AP600 that reactor in-vessel integrity is likely to be maintained but we acknowledged relatively large uncertainties in the processes involved. They are very complex.

These attempts to model this situation experimentally is quite difficult, the design experiments that faithfully reproduce it. One could argue whether the results are prototypic or not. We see large uncertainties in being able to predict things like the heat fluxes.

The general heat transfer expressions in and of themselves have uncertainties associated with them. In our review of AP600 we sponsor some work at INEL where they looked at alternate debris bed configurations such as the one that Jim kind of touched on that in his last few slides where he described the metallic layer that could sink to the bottom if sufficient uranium is dissolved and it becomes more dense.

You could have a heat-producing layer on the bottom. We postulated a couple of other scenarios. A thinner layer on the top, thinner than what was proposed in the Theofonous report.

We also postulated the possibility of kind of a sandwich steel layer where debris was both below and above the steel layer heating it from above and below. Perhaps it's a variation on this focusing affect.

But in recognition of all of those uncertainties, we think that it was prudent, and we did in the AP600, require additional calculations, deterministic calculations of ex-vessel phenomena.

So while within the PRA we have accepted the basic assumption that the brief stays in-vessel given that the two major success criteria are met, we did require, and similarly for AP1000, we are requiring ex-vessel calculations to be done to assure that in the event that the debris goes ex-vessel that the containment is not directly challenged.

With regard to each of these items here, reduced margins to CHF, impact of uncertainties, the work that we had done on AP600 indicated that while we expected things to stay in-vessel, the margins, we had much smaller margins because we had a model that solved the same governing equations as in the ROAM report but propagated through both parametric uncertainties, uncertainties in the correlations, and also looked at these alternative debris bed configurations.

When you take that additional information on balance, you would say chances are if you have that kind of configuration, it looks like you'll stay in-vessel but the margins are less.

Then if you have these other configurations, we're not so sure. Again, we went to this balanced approach where there is a reliance on in-vessel retention but yet we cover all the bases by looking at the consequences in terms of pressure loads if you go ex-vessel.

MEMBER SIEBER: One of the issues if you go ex-vessel is that you're going to end up going into this big pool of water that surrounds the vessel. The Westinghouse calculation basically says that there's plenty of margin for steam explosion. Have you looked at how much margin there really is?

MR. PALLA: Yeah. We're in the process of looking at it. Richard may talk to that if he's got some time. With regard to recent experimental work, the work that you heard Jim describe, the RASPLAV and the MASCA results and their applicability, we had a basic question given we've got several years between AP600 and now.

We've learned a lot of those tests have been completed in the intervening years. We ask what are the implications? What does that say about this stratified layer? We thought it may actually be that those tests are not as prototypic as one might hope for but there are insights that we want to make sure that we bring to bear on this whole question.

Another issue we raised was the thinned RPVs. Jim mentioned it. You look at the heat fluxes and the heat fluxes determine theoretically the thickness of the steel vessel that you're left with. I think the number was 36 times the amount required to accommodate the deadload.

If you look at the pressurization that might occur, if you have a small pressure spike within the vessel upon a reflood, for example, it looks like about 35 PSI might be enough to eat up that margin that you have. 35 PSI integrated over the cross-sectional area of the vessel and carried over a small thickness gives you what we thought to be some concerns regarding just pressure oscillations in the vessel being a structural load.

That's been addressed with some arguments based on expected pressurization rates for a couple of different situations. We have an REI response. We haven't really fully reviewed its adequacy yet. Design a thermal insulation is something, as Jim had mentioned again.

For AP600 the heat transfer situation is basically an open free pool of water that just bubbles freely. The details of the design of the insulation were not critical because there was no attempt to really optimize critical heat flux.

What we see with AP1000 is essentially the need to optimize that design, to maximize the CHF because that's necessary to accommodate the decay heat loads.

The way that one would take the experimental data, and perhaps, I guess, the ULPU Configuration 5 would be the best source of that data, but one has to determine the specifications that one would design this insulation system for to ensure that it maintains its structural integrity under the flooded up conditions with the kind of flows and pressure oscillations that one could see. If you've ever had a chance to look at the ULPU test facility, one thing that is pretty impressive is just the large degree of pressure oscillations that is apparent from looking at the test rig. There's like a plenum below the heated blocks. It basically has flat sides to it. When that test gets chugging away, you can just watch the sides of that little plenum chamber kind of oscillating.

During the AP600 review it became an issue of where are you going to get the pressure data from to design this insulation and how does it scale. It's on the table here. It's still a question that we are going to have to be dealing with.

We had some questions about hydrogen

control. We questioned the diffusion flame mitigation strategy. I think there was maybe a bit of confusion in the application where it appeared that Westinghouse was relying on a creep rupture calculation that they had done for AP600 as part of the mitigation strategy for AP1000 as well.

We question whether they really intended to do that and they have given us clarification. In essence the strategy does not rely on creep rupture. Rather, it has the hooded IRWST vents that will close and redirect the hydrogen to the more central areas of containment where it won't challenge the shell.

We asked some questions about ignitor placement velocity and the effectiveness. We had some concerns because the same number of ignitors are covering a larger volume. We wanted to make sure that there isn't the possibility to have increased concentrations as a result of the greater distances between that. We got a response on it and we'll be looking at that more closely.

Like in AP600 there is a nonsafety related containment spray header in this design. Kind of a follow-on from the AP600 carryover.

MEMBER SHACK: They didn't say much about it.

MR. PALLA: No. In fact, I thought that they might have included a top event in the event tree to deal with the effects of the spray that it might have. It has both potentially negative effects as well as the obviously positive effects of fission product scrubbing, but it could de-inert the containment when you were otherwise thinking it might be better to be inert sometime.

If you operate the sprays, you could create a flammable situation. It's really the same question that we asked on AP600. It wasn't modeled in the event tree there either. It's still not modeled here. We just want to make sure that there's nothing -- it's not going to create any kind of a risk or pervasion on the results.

Direct containment heating would appear to not be an issue. Admittedly the likelihood of high pressure melt events is quite small in this design but there is a little bit of a history behind the direct containment heating and how one deals with it in design certification.

I guess in 1993 in SECY 93-087 there is kind of a staff policy paper that went up to the commission. It said the staff's view is that advanced reactor vendors should design the cavity with features that would reduce the amount of debris that is disbursed to the upper containment and should provide depressurization systems. We have this qualitative criteria out there.

Subsequently around 1996 Sandia and the Office of Research completed work on a methodology to quantify the pressure loads from DCH events. When we reviewed AP600 Westinghouse in response to staff request provided quantitative assessment of the loads consistent with that methodology.

Now, for AP1000 we were expecting that one could make arguments as they had made arguments about masses in compositions being comparable to AP600. We didn't get that kind of an argument. The argument was we need those items specified in SECY 93-087. We got a depressurization system and we got the cavity that has these kind of features the staff was looking for.

We asked for a DCH mechanistic calc. We didn't get one yet so we'll probably be asking again to do that. We will at least have some dialogue on it. We would at least like to know that the pressure loads are comparable to the AP600.

With regard to core concrete interactions, one thing that's different as a result of the design being the higher power level, higher core masses, same exact footprint as far as the reactor vessel and the reactor cavity so naturally the debris debts are going to be different in the two designs.

In the initial application it did not indicate that there was any change being made to the cavity. In particular, there's a sump within the cavity. The sump is located -- the reactor vessel is on one side of the cavity. The sump is on the other side.

There's actually like an intervening wall with a doorway past that wall that goes into the other part of the cavity. The sump is on the far side. There's a curb around it. The curb was designed to be at a height such that I think the full core could reside in the cavity and not overflow the curb. That curb probably wasn't changed from AP600.

Analyses were submitted in the application that argued that it was not an issue. Debris in the sump would not be an issue but that was predicated on an assumption that metallic and oxide components of the debris would separate and that the metallics -- if you look at what ended up on the far side it would be primarily metallic. If you looked at what was below the reactor vessel it would be primarily oxidic.

Being skeptical, naturally, we thought

what if it wasn't that way. What if it was an uniformly distributed homogenous mixture that's spread out. We expected to see some calculations of that. We didn't get that yet. We did get an indication that the design has been changed.

The sump curb has been increased to accommodate what I think would be the full core, the fully inventory. We still have some questions about the core concrete interactions, the effect of the deeper depth of debris on basemat penetration.

The last item here is just three different areas where the application did not include the same level of information that was included in which we used in the AP600 reviews. Equipment survivability assessment was stripped of all of the details. Pressure and temperature histories have now been provided in response to that.

Important analyses results, some of which Jim presented, I think were lacking in the submittal but were provided subsequently.

CHAIRMAN APOSTOLAKIS: Who cares? Does anyone use those?

MR. PALLA: I just threw it in there. No. It was for completeness. What I did here was I summarized what we were asked for and now you've heard it.

CHAIRMAN APOSTOLAKIS: Are you going to take any action based on these results? No.

MR. PALLA: My point was if you looked only in the submittal, you won't find these things.

CHAIRMAN APOSTOLAKIS: I understand that.

MR. PALLA: You have to go to the RAIs and the modified and there will be an update to it. That was the only point. With that done, Richard can fill you in on the research activities.

CHAIRMAN APOSTOLAKIS: I mean, it's not like we're talking about --

MR. PALLA: It was missing information. We're not even saying there were problems in those areas. We're just saying there wasn't any information submitted.

CHAIRMAN APOSTOLAKIS: By the way, we are still categorizing SSCs as seculated and nonseculated. Right? I guess later you will probably consider option 2 yourself. We wonder why not now. It's because of regulations.

MR. LEE: Thank you. As Bob mentioned, I hate to disappoint you, Dr. Seiber. We don't have -- excuse me? We haven't got the results yet for this analysis. It's about one and a half month away before we finish all this analysis.

I will walk you through what type of analysis we plan to do to address some of the severe accident related issues that we like to know for the AP1000 and to help in the design certification within the next two months.

I would like to mention that besides me in the Office of Research, there are two key persons. Dr. Basu helps us with the analysis and FCI related stuff. Also on the MELCOR concrete interactions. In the in-vessel retention, Dr. Behbahani is involved with a lot of the RASPLAV project and the MASCA, as you mentioned earlier. That is an area that we will be concentrating on plus other things.

We have contracted with ERI to do these MELCOR analysis.

CHAIRMAN APOSTOLAKIS: With whom?

MR. LEE: Energy Research Institute, ERI, with Dr. Mohsen Khatib-Rahbar. As you can see here, the reason is that we are using MELCOR. Dr. Ransom earlier asked us whether you can use MAAP. MAAP doesn't give you detail on melt progression inside in the severe accident arena but MELCOR does.

It's comparable to the SCDAP 5. We decided we are going to use the MELCOR code to do our analysis to get some of these initial conditions and mass and so we can do the other subsequent analysis.

The MELCOR 1.8.5 we are using now are different from the one that we used back in the AP600 analysis a while ago. So we went back and we also benchmarked the new code against the previous code and looked at the results to make sure that they are comparable in terms reasonably giving the similar results. So we benchmark against AP600 first and now we modified the data for the AP1000. And that has been completed recently.

We also get a lot of information through Westinghouse, and also they give us the MAAP, which give us a lot of information we needed for our analysis.

Now, you understand that the MELCOR has some limitation in terms of doing the in-vessel retention type analysis because the model -- earlier you asked us whether we have a monitor can do the melt partitionings and whether the fission products will go to the right place.

We are in the process of this year implementing such a model in MELCOR but it's not available for our purpose here so we are going to do the sequence analysis, look at the melt mass composition and so forth and we are going to use a separate model to do the in-vessel retention analysis.

We also have the model that Jim mentioned from INEL and CRI has it. We found the same error that you did. We think that the analysis we show about looking at equivalency, that is a valid methodology that you're using. We intend to do the same thing but with the models with a hemisphere.

From that we are going to look into the base on what the MELCOR compilations we find. We can look at all the different type configurations. For example, if you have metal down there with oxidic melt, and then on top you have another thin layer of metallic, we can look at all those variations with a separate analysis. That is what we intend to do for the in-vessel retention questions so we can explore the whole range of it.

Let me show you a viewgraph that is not in your handout. These are the results from the MASCA project. There are four tests here. It started with a composition of this and these are the metal part. It ends up with a composition which this one is oxidic and this one is metallic.

You can look at how much is oxidized and this tells you the uranium zirconium ratio. These are the full tests. You can see that it depends on the type of additives you put in. You can see that the subsequent compositions are different.

That gives you some idea that even though you started off with these two material, they end up in the different configurations based on different conditions. These are the type of insights we like to look into for our in-vessel retention analysis.
If ACS want to listen to the start presentation from Research on MASCA in the future, we will be glad to present that to you in details.

The sequence that we have chosen to do the analysis, as you have seen here, are from the Westinghouse one, two, and three which are frequency dominant sequence 29, 18, and 9. We also chose one, No. 20.

Actually, we asked them for some more clarification on this sequence and we subsequently received some of the information but we may need to have some more. Do you have some more questions on that?

PARTICIPANT: There will be some minor questions.

MR. LEE: So there are some minor questions that I think we can clear with you. This has to do with something with whether this is really drained directly into the cavity and about the IRWST, these two items here. This is really, I think, just clarification. These are the four sequences we intend to base our calculation on.

CHAIRMAN APOSTOLAKIS: Of course, again, I have the same problem with your description on the left of the last LOCA. The sequence that you are referring to, 18 percent of the total is just large LOCA and failure of one accumulator. It doesn't say anything about RHR or BRHR or CMT. I don't know how that would affect your calculations. That's block damage state 3BR.

MR. LEE: That's correct.

CHAIRMAN APOSTOLAKIS: Maybe you put it there for completeness.

MR. LEE: Yes. That's what it is. Because this is a low-pressure sequence, this is somewhere over medium and this is something high.

MR. KHATIB-RAHBAR: Excuse me. This is Mohsen Khatib-Rahbar. George, whatever is listed as a description of a scenario are those which are credited in the calculation. They are not just for listing those items. These are reproduced from the Westinghouse document. We are not looking at why CMTs are operating for large LOCA and similar to core damage, etc. We are taking those as given.

CHAIRMAN APOSTOLAKIS: Well, if I read the description of the large LOCA event tree for that sequence, they say that the core makeup tanks are insufficient so they stop part of the event. For the other sequences they are.

MR. KHATIB-RAHBAR: For these they are also insufficient. You go to core damage.

CHAIRMAN APOSTOLAKIS: Yeah.

MR. KHATIB-RAHBAR: Right.

CHAIRMAN APOSTOLAKIS: The sequence that leads to -- it's not really 18. It's 19 something -- is 3BR which is the lowest one.

MR. KHATIB-RAHBAR: This is one of the sequences. This is the dominant one in 3BR. Exactly. It's 18 percent, I think, of the 19 percent that you have. Yes.

MR. LEE: So this forms the basis for our getting the initial conditions for subsequent analysis which is looking into other sensitivity analysis in the ex-vessel for MCCI.

In this one here we plan to use the core coat stand-alone model to do the analysis so we can do also variation because we don't really need to use the whole core to do the analysis for this one over here.

We also are going to look into the containment spray operation that is within MELCOR itself. The reason we are looking into this because the spray now is located -- the containment is taller so I believe the flow rate is still the same. We think the efficiency will become a little bit lower because the drop intensity will be lower and the drop calculations. Because of those two reasons. This is to look into what impact this has had on the containment loads, pressure and temperature as well as fission power scrubbing, too.

What I didn't mention here that we will do the FCI in-vessel, ex-vessel separately, too. For those we have many options. I think the PM-ALFA astro, we are going to use that. We also have the option to use Texas coat from the University of Wisconsin for the FCI analysis.

I think we expect to finish all this within about a month or so and we should be able to tell you something more by that time. I'm not too sure if you're interested in looking at these. This is the MELCOR deck. This is the vessel, the steam generators, and simulation for all the rest of the components here. This is the nodalization for the containment.

As a matter of fact, at this time we have already finished one of the calculations on the 3BE but we haven't looked at the results yet.

MEMBER RANSOM: Each one of the boxes, is that a control volume or node in MELCOR?

MR. LEE: Yes.

MEMBER RANSOM: So you have composition and what flows from one to the other?

MR. LEE: That's correct. For example here, if I'm correct, we didn't show all the detailed nodes in here. The five-ring model is here with the 10 axle nodes. The MELCOR 1.8.5 -- MELCOR used to only have three rings and 10 axle nodes but we try to maintain only one code instead of maintaining SCDAP 5 and MELCOR so we make MELCOR and improve it to be 5 rings.

The reason is SCDAP 5 has 5 rings. When we do comparison between different type of analysis between SCDAP 5 comparison we want to have one-to-one comparison between the nodes. Now we have developed a 5-ring model for MELCOR. We can tell details of melt progression inside over here. Within this frame work we can analyze how AP1000 melt progression will look like.

CHAIRMAN APOSTOLAKIS: Is this a major effort?

MR. LEE: Which one?

CHAIRMAN APOSTOLAKIS: As such you described.

MR. LEE: For which one?

CHAIRMAN APOSTOLAKIS: The whole thing.

MR. LEE: The model here, we started this back like in October of last year. We have an AP600 deck and I think --

MR. KHATIB-RAHBAR: It's a few months of effort.

MR. LEE: We mostly converted it in two months. We did a QA on it.

CHAIRMAN APOSTOLAKIS: Out of curiosity, take 3BR. Frequency is 4.6 events every 100 million years. 4.6 events every 100 million reactor years. How low would you have to go for you not to do anything? Why are you doing all this? I mean, this is an incredible event. There may be two answers. One is defense-in-depth, the structure of this approach. No matter what you do in Level 1 I want to spend --

MR. LEE: That's right.

CHAIRMAN APOSTOLAKIS: The other one that you don't believe the number. Between a rock and a hard place.

MR. CORLETTI: Can we vote?

CHAIRMAN APOSTOLAKIS: I'm serious. How low does it have to go? Every billion reactor years? Where do you draw the line?

MR. PALLA: I guess --

CHAIRMAN APOSTOLAKIS: Defense-in-depth?

MR. PALLA: No. I was just going to say that I think what you draw from these kind of analyses -- you can argue just how many analyses do you need to do. We thought that a few analyses would be not that intense of an effort given that we were starting with a deck that was already available so relatively straightforward changes to the deck to account for the changes in the designs.

And then some sequences that could be used to assess and to confirm the general nature of the accident progression because you can't get wed to the exact specifics of these kinds of scenarios anyway. The uncertainties in accident progression are quite significant code to code. Even within the same code you could perturb the sequence and end up with substantial differences.

We would look to these as general

confirmation that, yeah, the calculations used as the basis for the AP600 PRA are in general agreement in terms of the order of the events and the general timing of the events.

CHAIRMAN APOSTOLAKIS: What you just said gives me -- makes me think of something that occurred to me this morning.

MR. PALLA: But you could confirm, like fission products, for example, could be confirmed. Order of magnitude confirmation. Once you've run the calculation you can do simple sensitivity studies like turn on the sprinklers and let the thing go ex-vessel and let it oblate concrete and see if you are in the same ballpark with pressurization rates, oblation depths. We didn't view it as a major sinkhole of resources.

CHAIRMAN APOSTOLAKIS: You just said something just now that there is uncertainty within the code, model uncertainties. I remember now -- I don't remember, I look at the figures that Jim presented this morning. You're talking about condition containment failure probability of .07, .08.

Based on what you just said and what I remember from 1150 this would be anywhere from zero to what? What am I learning from all this? I'm trying to understand what I'm learning from this. I'm learning nothing.

MEMBER RANSOM: Is it possible these are the high consequence situations? I mean, if you put it in terms of number of depths for reactor year of operation, do these contribute more than some of the others?

CHAIRMAN APOSTOLAKIS: I don't know. Do they? They certainly run high with respect to core damage frequency.

MR. BASU: George, this is Sud Basu from the Office of Research. There is a third answer. We need initial and bounding conditions for other analysis such as FCI, such as CCI. We need to do MELCOR calculations.

CHAIRMAN APOSTOLAKIS: CCI stand for?

MR. BASU: Core concrete interactions.

CHAIRMAN APOSTOLAKIS: Why do I have to worry about that? Selim has done such a great job. Why do I have to worry about that?

MR. BASU: Okay. Now, if you want to rely entirely on the frequency argument without --

CHAIRMAN APOSTOLAKIS: Ah, it's defense of that.

MR. BASU: There you go. Thank you.

MEMBER SHACK: Structuralist.

MR. LEE: Maybe we will find out it's better than what they claim so you should worry less even about it.

CHAIRMAN APOSTOLAKIS: I don't worry.

MR. LEE: Right. I don't either.

CHAIRMAN APOSTOLAKIS: I'm really skeptical about the value of these numbers that we're getting at the end, even the uncertainties. It's between zero and what? Anyway, do you have anything else to say?

MR. LEE: No.

CHAIRMAN APOSTOLAKIS: Bob? Any members? Westinghouse? Thank you very much.

MR. LEE: Thank you.

CHAIRMAN APOSTOLAKIS: According to the schedule, we are going back to Mike, right?

MR. CORLETTI: This is Mike Corletti, Westinghouse. I don't think it's very useful to go over any more slides.

CHAIRMAN APOSTOLAKIS: Unless you have something interesting.

MR. CORLETTI: No, not really. Perhaps at this time it's just best to talk about the next steps as far as future meetings. First of all, I want to thank you all for the two days of meetings. The questions give us good insight and some more things to think about.

All in all hopefully we have met your expectations for providing you information. I'm sure we'll be hearing more about that if we haven't. In any event, I think the next interaction that we have with the ACRS will be, Med was just telling me, March 19th and 20th which we'll have a thermal hydraulic subcommittee. I think if you look in your book I had listed -- I think it's on slide 5. No, slide 6. Maybe it's slide 7.

CHAIRMAN APOSTOLAKIS: Slide 7, ACRS meeting.

MR. CORLETTI: Yes. As far as the subject matter, I think for the thermal hydraulic do you have any input as far as additional topics for the thermal hydraulic meeting? I think that's probably a full plate with safety analysis, the issues of entrainment and the Oregon state testing that's going on. It think that's what we planned on discussing at that meeting.

Then I think that I show April but I believe the meeting will actually be in May, a plant subcommittee according to what Med said. There we will talk about -- I think the issues are listed.

Plus I think there is an additional issue of man machine interface that the committee would like to hear about as far as what our plans are for AP1000. I don't have any that can come off the list. I think the best is to talk amongst yourselves and work with Med to give me any other changes to that.

Then I believe we'll have a meeting in June to close out any open items that may come from that meeting, so May and June, and then have a full committee meeting in July. The July meeting we would be looking for a letter.

MEMBER LEITCH: One of the things in that plant system meeting -- that's not quite the right term for it -- in April or May, I guess I would like to be able to take a look at what I would call P&IDs of particularly the passive safety systems.

There were some P&IDs along with the CDs that you sent us on the PRA, but it seemed like there was two versions of them. One was a very, very simplified system drawing which was not useful for the purpose that I wanted to look at.

Then another one was a P&ID that was hopelessly compressed. If was just difficult to read. I'm looking for something that is kind of in between that other than hard drawings how to do that, I guess.

MR. CORLETTI: Is it that you would like a -- we could submit our P&IDs to review a bigger version of the compressed one, of the detailed one?

MEMBER LEITCH: Yeah, I think that would satisfy my need. It wasn't that it had too much information. It was just --

MR. CORLETTI: It was 11 by 17 version of a --

MEMBER LEITCH: Actually it was 8 1/2 by 11.

MR. CORLETTI: Okay. We have half-size drawings. The DCD has an 11 by 17 version. Do you have a hard copy of the DCD?

MEMBER LEITCH: No.

MR. CORLETTI: So you probably have the CD.

MEMBER LEITCH: CD, yeah.

MR. CORLETTI: What we submitted is 11 by 17 which maybe we can get a copy of that, Jerry?

MR. WILSON: This is Jerry Wilson. Yeah, there are. Mike, don't you have hard copies?

MR. CORLETTI: We should be able to check with Med and see if we have the hard copy. I'm pretty sure we do. If we don't, we can work with --

MR. EL-SADAWY: We just have one hard copy of the whole DCD. What we had is the CDs that all members received.

MR. CORLETTI: How about if we prepare a package of information that is a docket of information that is the P&IDs but we'll just collect it in a package of 11 by 17 drawings and we can furnish X amount of copies.

MEMBER LEITCH: That would be helpful to me.

CHAIRMAN APOSTOLAKIS: Are you done, Mike?

MR. CORLETTI: I'm done.

CHAIRMAN APOSTOLAKIS: Thank you very much. Thank you and your colleagues for taking the time.

MR. SNODDERLY: George, this is Mike Snodderly. I just wanted to thank Mike Corletti for all his support in preparing this material for the committee and the presentation. And also I wanted to say something about Larry Burkhardt from the staff. He was very helpful in helping us to prepare for this meeting. Thank you.

CHAIRMAN APOSTOLAKIS: Okay. The last part of the day and a half is to go around the table and you gentlemen will tell me what you think about

AP1000. Shall we start with Jack?

MEMBER SIEBER: Well, as far as I'm concerned, I thought this for me was a pretty good learning experience because I'm not a PRA expert so the documentation was put together very well that I could understand it.

It seems to me from what I do know that the techniques and the calculations that you did are pretty straight forward and pretty standard. There were no surprises or places where I would feel inclined to scratch my head and doubt the information you put forth.

On that basis, I think the PRA document was well prepared and relatively easy to understand and your presentations were good. I don't have any negative comments at this time.

CHAIRMAN APOSTOLAKIS: Thank you. Bill.

MEMBER SHACK: Superb presentation. I found it very helpful. Reading through a PRA is kind of a painful thing. I thought the presentations were very well prepared. I feel pretty good about AP1000.

CHAIRMAN APOSTOLAKIS: So it's not just the presentation. It's the content as well.

MEMBER SHACK: Yes.

CHAIRMAN APOSTOLAKIS: It feels good.

MEMBER SHACK: It feels good. Warm feeling.

CHAIRMAN APOSTOLAKIS: Vic.

MEMBER RANSOM: It was a very good presentation and learning experience for me. The only thing I found a little bit surprising, I guess, were your comments in the end where it seemed like an awful lot of work had gone into this rather complex accident type situation with many things that I think the thermal hydraulics committee would obviously like to look into, I guess, or should.

On the other hand, if it has very little consequence, I'm wondering why did so much effort go into that and not more into the higher consequence things, I guess. It was a good learning experience.

CHAIRMAN APOSTOLAKIS: Remember that when we discuss philosophical operations in depth. Are you finished?

MEMBER RANSOM: Yes.

CHAIRMAN APOSTOLAKIS: Okay. Graham?

MEMBER LEITCH: Well, like my colleagues, I found the presentations very helpful. I thought they were well done. I think the staff has identified a number of appropriate issues that are still undetermined or are being worked on at the moment.

I think there are a number of issues there that we need to hear the resolution of those issues, and obviously we will. I think that as we went through the presentations and then I heard the staff comment indicate where they still had some questions, I thought it was largely in line with the issues that I had in mind as well. I think they have identified the right issues and we just need to work our way through the resolution of this.

CHAIRMAN APOSTOLAKIS: Tom?

MEMBER KRESS: Well, I, too, though we had a very good PRA and a good presentation. I was a little bit shaken, like you were, about the state of the uncertainties but I don't think it matters very much.

The only areas where I still want to convince myself a little bit on are the squib valve reliability. I'm looking forward, like Steve is, to seeing the database that backs that up.

I still wasn't quite convinced mainly because I didn't have time to digest it all on the in-vessel retention and whether or not we found the worst configuration or the most problem configuration and whether or not it would fail the vessel.

Then I haven't -- we didn't see much

detail on the fuel-coolant interaction ex-vessel that we were all told is the same energetics as the AP600. I've forgotten what the AP600 energetics were and what they were based on so I've got to go back to the old ROAM and see what they did there.

Assuming that was acceptable then, it's probably acceptable now and they have a bigger, stronger containment here. It probably doesn't affect anything in the sense of the PRA. Staff, I think, appears to have asked the right questions and I'm anxious to see what kind of responses we get from them. All in all I don't see any show stoppers. I think it looks pretty good.

CHAIRMAN APOSTOLAKIS: Let me ask you gentlemen, you heard that the core damage frequency is what, 2. --

MEMBER KRESS: 4 times 10 to the -7.

CHAIRMAN APOSTOLAKIS: 4 times 10 to the -7. 2.4 events.

MEMBER SHACK: Internal events.

CHAIRMAN APOSTOLAKIS: Internal events every 10 million reactor years. Your gut feeling. How high do you think it could be given all the uncertainties that we have? They say it's a factor of 6.

MEMBER KRESS: I think it could be as much as 2 orders of magnitude

CHAIRMAN APOSTOLAKIS: So that would make it 2.--

MEMBER KRESS: The question what's the probability of it being --

CHAIRMAN APOSTOLAKIS: Right. So the 95th percentile would be still on the order of 10 to the -5 which is pretty.

MEMBER KRESS: Which is all right.

CHAIRMAN APOSTOLAKIS: Anybody else?

MEMBER SHACK: I don't see it from uncertainties, George. The nagging fear is that you've missed something. It's the completeness argument. I think you could analyze uncertainties until hell froze over.

CHAIRMAN APOSTOLAKIS: No.

MEMBER KRESS: I'm basing my 2 orders of magnitude on sort of the NUREG-1150 thinking which is supposed to incorporate that kind of thought.

MEMBER SHACK: Well, I don't know how to incorporate any completeness as an uncertainty.

CHAIRMAN APOSTOLAKIS: From the overall quality of what you heard and the review that the staff is doing, surely you don't think they missed something that has a probability of 1.

MEMBER SHACK: No. 10 to the -8, that's getting pretty tough.

CHAIRMAN APOSTOLAKIS: Do you think the contributor will be found six years from now that it would be 10 to the -3?

MEMBER SHACK: No.

CHAIRMAN APOSTOLAKIS: That's what I'm saying. You agree then with Tom?

MEMBER KRESS: When I start putting uncertainties on I talk about things like --

CHAIRMAN APOSTOLAKIS: I include incompleteness.

MEMBER KRESS: Yeah, I do, too.

CHAIRMAN APOSTOLAKIS: I include incompleteness. I am not like God.

MEMBER KRESS: If you didn't have incompleteness in there, you would only get an order of magnitude higher.

MEMBER SHACK: But I don't know what you do with incompleteness.

CHAIRMAN APOSTOLAKIS: Yeah, but you do know that it's not 1. You do, I think, believe that it's not 10 to the -4.

MEMBER SHACK: That's engineering

judgment, George.

CHAIRMAN APOSTOLAKIS: What else could you give me?

MEMBER SHACK: When it comes to things like the large break LOCA frequency, those numbers to me are probably conservative for pipe breaks. It's this notion is there some other way I can get a large break LOCA that I haven't thought about.

CHAIRMAN APOSTOLAKIS: But even that is not so unknown.

MEMBER SHACK: No. If I raise it by an order of magnitude, you know, it would still look pretty good.

MEMBER SIEBER: There's only so many things you can break.

CHAIRMAN APOSTOLAKIS: Sorry?

MEMBER SIEBER: There's only so many things you can break.

CHAIRMAN APOSTOLAKIS: Or open.

MEMBER SIEBER: Or open.

CHAIRMAN APOSTOLAKIS: So it seems to me that we have a consensus here that this is a very good piece of work.

MEMBER KRESS: It looks pretty good to me.

MEMBER SHACK: The other one is the plant protection system. You know, those numbers.

CHAIRMAN APOSTOLAKIS: But, again, you know, when you find yourself in situations like that, start with extreme numbers. Is it too high? No, I don't believe it. Then you start working down and then pretty soon you have some fairly good idea.

I mean, you cannot say it's 6 times 10 to the -5 but some range. I believe most people here at the table, if not all, believe even if you look at the high-pressure the level would be below the goal.

MEMBER SHACK: I'm still glad to have a containment.

CHAIRMAN APOSTOLAKIS: I don't know why. Then those low numbers will go up in the name of defense-in-depth. But then we are not reviewing the errors of commission because we have never seen those. Right? We've seen many challenges to the containment but never errors of commission.

MEMBER RANSOM: One added question, I guess, would be is there any thought about considering terrorist-type acts and including that in a PRA?

CHAIRMAN APOSTOLAKIS: Not in the certification process. Don't look at me like that.

MEMBER RANSOM: It seems to me that would be an event that might be more likely than many of the things we have heard.

MR. ROSENTHAL: This is Jack Rosenthal, Safety Margins and Systems Analysis Branch in Research. This is an open meeting and I don't think that is the forum to discuss it, but we could discuss issues in some other forum.

CHAIRMAN APOSTOLAKIS: That's your answer. Anything else? Well, thank you very much. I would like to thank you again and the staff for taking the trouble to come here and prepare these presentations. Yes, I would add my congratulations also to you. It was a great presentation. Especially when Selim says that we can talk about it philosophically forever and never reach a conclusion. Thank you all. This meeting is adjourned.

(Whereupon, at 2:20 p.m. the meeting was adjourned.)