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TR04

1 UNITED STATES OF AMERICA

2 NUCLEAR REGULATORY COMMISSION

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4 MEETING

5 ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

6 (ACRS)

7 SUBCOMMITTEE ON MATERIALS AND METALLURGY

8 + + + + +

9 WEDNESDAY,

10 FEBRUARY 5, 2003

11 + + + + +

12 ROCKVILLE, MARYLAND

13 + + + + +

14 The Subcommittee met at the Nuclear Regulatory

15 Commission, Two White Flint North, Room T2B3, 11545

16 Rockville Pike, at 8:30 a.m., Dr. William Shack, Vice

17 Chairman, presiding.

18 COMMITTEE MEMBERS:

19 WILLIAM J. SHACK, Vice Chairman

20 SANJOY BANERJEE, Consultant

21 MARIO V. BONACA, Member

22 F. PETER FORD, Member

23 THOMAS S. KRESS, Member

24 GRAHAM M. LEITCH, Member

25 VICTOR H. RANSOM, Member

1 STEPHEN L. ROSEN, Member

2 GRAHAM B. WALLIS, Member

3 ACRS STAFF PRESENT:

4 RAMIN ASSA

5 RICHARD P. SAVIO

6 ALSO PRESENT:

7 ALAN KOLACZKOWSKI

8 DAVID BESSETTE

9 ED HACKETT

10 MARK KIRK

11 MICHAEL MAYFIELD

12 JACK ROSENTHAL

13 NATHAN SIU

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I-N-D-E-X


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

8:34 a.m.

DR. SHACK: This is the meeting of the ACRS Subcommittee on Materials and Metallurgy. I am William Shack, Vice Chairman of the Subcommittee. The ACRS members in attendance are Mario Bonaca, Peter Ford, Tom Kress, Graham Leitch, Steve Rosen and Graham Wallis and Vic Ransom.

Our Consultant, Mr. Sanjoy Banerjee, is also is attendance. The purpose of this meeting is to review Staff's draft report on the technical basis for revision of the pressurized thermal shock screening criteria in the PTS Rule 10 CFR 50.61.

The Subcommittee will gather information, analyze relevant issues and facts and formulate the proposed positions and actions as appropriate for deliberation by the full committee.

Since I am involved in NRC sponsored work at Argonne National Laboratory on the air oxidation of zirconium cladding, I will not participate in any deliberations relating to that work.

Dr. Kress will act as Subcommittee Chairman during these discussions, should they occur. Richard Savio is the designated federal official, and Ramin Assa is the cognizant ACRS Staff Engineer for

1 this meeting.

2 The rules for participation in today's

3 meetings have been announced as part of the notice of

4 this meeting in the Federal Register on January 21st,

5 2003. A transcript of this meeting is being kept and

6 will be made available as stated in Federal Register

7 Notice.

8 It is requested that speakers first

9 identify themselves, use one of the microphones, and

10 speak with sufficient clarity and volume so that they

11 can be readily heard. I would like to point out that

12 copies of the staff's presentation are in the back of

13 the room.

14 In addition, a few copies of the draft

15 report are also available for reference in the back of

16 the room. We have received no requests for time to

17 make oral statements or written comments from members

18 of the public regarding today's meeting.

19 We will now proceed with the meeting. I

20 call upon Mr. Mike Mayfield, Director for the Division

21 of Engineering Technology, Office of Nuclear

22 Regulatory Research, for opening remarks.

23 MR. MAYFIELD: Good morning. Thank you,

24 Dr. Shack. Let me start by apologizing to the

25 committee and the audience. Our lead presenter is

1 hung up in traffic and he hopes to be here, he said in
2 five to ten minutes. Based on his ability to forecast
3 schedules, I'm not optimistic.
4 (Laughter.)
5 MR. MAYFIELD: So, we'll see. Once he,
6 the other dilemma is that he does have the computer
7 that contains the only copy, electronic copy of the
8 slides. So, what we've proposed to do --
9 DR. SHACK: Redundant back up systems
10 here?
11 MR. MAYFIELD: Pardon me?
12 DR. SHACK: Defense-in-depth.
13 MR. MAYFIELD: We've apparently failed
14 open here, yes. So what we would propose to do is do
15 this the old fashioned way, as it was suggested
16 earlier, and start with -- Nathan Siu has volunteered
17 to step forward and start the presentation.
18 Once Dr. Kirk arrives, then we'll get the
19 computer hooked up in short order and continue with
20 the presentation. I don't think that based on the
21 degree to which there has been an interdisciplinary
22 approach and a number of staff members have been
23 heavily involved, I don't think the committee will
24 suffer for lack of technical content.
25 It's just a bit of irritation in the way

1 we're going to have to present it. This meeting does
2 represent a major milestone for us in, along the path
3 we've had with the PTS Project.
4 This has been a major undertaking for us.
5 All three technical divisions in research have been
6 heavily involved. We've had the benefit of a number
7 of meetings with this Subcommittee and the Thermal
8 Hydraulics Committee.
9 So this has been something where we have
10 benefitted from a number of interactions with you and
11 we'd hope that your comments and concerns have been
12 taken into account appropriately along the way.
13 And that you're going to be as pleased
14 with the product that we have as we are. We have
15 briefed up through senior management in the
16 organization and they have expressed their general
17 satisfaction with the project, but they are also
18 keenly interested in what the committee may have to
19 say.
20 So, with that, I would like to introduce
21 Dr. Nathan Siu, and let him begin our presentation.
22 DR. SIU: Good morning. I'm Nathan Siu
23 with the Office of Research PRA Branch. And I'm no
24 Mark Kirk, but I'll try to step in and do this
25 presentation. I've heard it a few times and hopefully

1 I'll do it some justice.

2 With me are Dave Bessette, Ed Hackett and
3 Alan Kolaczkowski. What we're going to do in the
4 morning is to talk about the approach that was taken
5 in the re-evaluation project and then later on we'll
6 get to the plant-specific results.

7 I guess I suggest to the Subcommittee that
8 we can certainly be flexible in the agenda that you
9 see posted. So if you'd like to take more timely,
10 obviously, on the plant-specific results and less time
11 on some of the later items in the agenda, that would
12 be just fine.

13 And we'll just adjust our presentation
14 accordingly. Okay. The first slide shows some of the
15 principle team leaders here. Again, Mark and Ed on
16 the Probabilistic Fracture Mechanics.

17 Roy Woods, sitting in the back, on the
18 PRA. Donnie Whitehead from Sandia National
19 Laboratories, Alan Kolaczkowski from SAIC. Also the
20 PRA leads. Dave Bessette on Thermal Hydraulics.

21 We haven't listed University of Maryland
22 contributors, with James Chang helping us on Thermal
23 Hydraulic Uncertainty, for example, is also here in
24 attendance. And so we have a number of folks who can
25 answer questions as the need arises.

1 Our second slide shows, again, the
2 proposed agenda, which you have in front of you. So,
3 and the notion would be we'd provide an overview and
4 background before the break and then get into
5 plant-specific results after the break.
6 And then let the presentation go where it
7 will at that point. And as you see we have a massive
8 number of slides and so I'm sure we won't cover
9 everything that's in those slides.
10 Our third slide shows the government and
11 industry participation. This has been an activity
12 that has been supported tremendously by industry.
13 Specifically the MRP and EPRI. And you'll see a
14 number of the organizations involved here.
15 We had to do plant-specific studies as
16 part of this work, and without the cooperation of the
17 utilities and other members in the industry we
18 couldn't have gotten the job done.
19 We've also had very good reviews along the
20 way of a number of the technical products and tools
21 and interactions are still continuing in that area.
22 DR. WALLIS: This is very good, but I
23 think when one reads the documents you put out, like
24 the NUREG, it's clear that different bits were written
25 by different people? Is this think working?

1 DR. SIU: Yes.

2 DR. WALLIS: And someone needs to put it
3 all together so the whole story is perhaps clearer.
4 That's an observation I have. And if you have too
5 many cooks and not enough time to put together the
6 main dish and explain it.

7 DR. SIU: Yes, thank you for the comment.
8 And that's certainly an important point. We've tried
9 to present an integrated approach, but clearly there's
10 some places where the integration wasn't as good as in
11 others.

12 MR. HACKETT: I think one of the points
13 we'd add here, too, is the fact that in briefing this
14 with the Office Director, there have been numerous
15 opportunities for public interaction.

16 All the meetings with the groups that you
17 see here. We just had one recently, for instance,
18 just two days ago, where there was a public meeting
19 with a lot of these entities here. But also the
20 opportunity for public participation.

21 In practicality, there hasn't been a whole
22 lot of interaction with other interested members of
23 the public of late, but that said opportunity has been
24 availed, you know, for at least the last two or three
25 years now.

1 DR. FORD: On that point, public
2 interaction, is it literally people off the street, or
3 is it informed professors from fracture mechanics or
4 whatever it might be?
5 MR. HACKETT: It actually, when we started
6 this out was, I believe, April, 1999, is when we
7 kicked the project off. And there was interest at
8 that point from the types of news and press
9 organizations that covered the NRC typically.
10 I don't believe there's typically been a
11 whole lot of interest other than that. And I think,
12 frankly, this topic, as technically complex as it is,
13 I think some folks in that regard lost interest along
14 the way.
15 So we haven't had that same level of
16 participation. But we've gotten questions, you know,
17 along those lines. So that, you know, that
18 availability has been there.
19 DR. FORD: The reason for my comment
20 relates to one of the comments that you had, Graham.
21 In Thadani's covering letter for this NUREG document
22 it intimates that the ACRS is the only Peer Reviewer.
23 That cannot be the case, I hope.
24 MR. HACKETT: No, in fact that's not the
25 case. We have a detailed Peer Review that's basically

1 been engaged right now. We're hoping to complete
2 that this year.
3 DR. FORD: But it hasn't happened yet. I
4 mean Thadani says there has been a thorough Peer
5 Review. And when you read his letter you find out,
6 now who is this Reviewer? It's the ACRS. No, we are
7 not Peer Reviewers of your report.
8 MR. HACKETT: Let me back up a bit. There
9 have been a couple of things we've done, early on in
10 the project, that as Dr. Wallis indicates, there needs
11 to be more than that.
12 Early on in the project we engaged Dr. Tom
13 Murley, he's a former Director of NRR. And Dr. Murley
14 did a, I guess we'd call it, that's not a Peer Review
15 either.
16 He did a technical and programmatic
17 critique of what we were proposing at the time. He
18 wrote a letter to the NRC, I think it was to Ashok,
19 that was fairly complementary of the approach we were
20 taking.
21 So that's just an element of the type of
22 thing we've been doing throughout the project. There
23 is the continual interaction with the committee, which
24 we obviously appreciate, but does not substitute for
25 a Peer Review.

1 But frankly we have gotten a lot of
2 detailed comments from the committee and subcommittee
3 and full committee that we have addressed and are
4 continuing to address, so I think that's been very
5 valuable.
6 But that is not the substitute for a
7 detailed Peer Review. We have that activity engaged.
8 It's not completed right now. We are expecting we
9 will complete that in 2003. So that's where we are
10 with that one.
11 DR. RANSOM: I'd like to add a little bit
12 to Professor Wallis' comments on the documentation.
13 I know that in the main document, I guess that you are
14 going to present today, there was very little or no
15 explanation of why the heat transfer coefficient and
16 the downcomer is relatively unimportant to this
17 analysis.
18 And you have to read this other report by
19 University of Maryland to find out why that is. And
20 I'm wondering what is the relationship between this
21 report and, you know, the main NUREG? And I'm hoping
22 that will be answered, I guess, today.
23 MR. HACKETT: Let's see if Dave can
24 address that one.
25 DR. SIU: Do you want to get that now or

1 maybe we can address that later on in the discussion.

2 DR. RANSOM: Yeah, that's fine.

3 DR. SIU: Thank you for the comment. Mark

4 Kirk is clearly here. He's setting up the computer,

5 in body at least. So I guess I'd propose that we just

6 wait for Mark to set up.

7 MR. ROSEN: You beamed him up, right?

8 (Laughter.)

9 DR. KIRK: I apologize for my lateness.

10 One needs to allow a considerable margin in chaotic

11 systems and I think we can all be glad that PTS isn't

12 one of them.

13 DR. WALLIS: No, I think we have, now we

14 have a data point on your appreciation of the need for

15 conservatism.

16 (Laughter.)

17 MR. ROSEN: But it's only one data point,

18 we can draw any line through that we choose.

19 DR. SHACK: We can get a full

20 distribution.

21 DR. KRESS: You can draw a circle through

22 there.

23 DR. WALLIS: No, one data point is enough

24 to demolish a theory which claims to be correct. I

25 think consistent with that theory. Well, if he claims

1 to be absolutely correct.

2 DR. KRESS: Well, we could let Dave

3 Bessette answer your question while we wait.

4 MR. BESSETTE: If you want. The main

5 NUREG is not necessarily intended to be completely

6 stand alone. But it will reference the University of

7 Maryland report which itself will be a NUREG/CR,

8 released as a NUREG/CR in the coming months.

9 DR. RANSOM: The strange thing is his

10 question is answered in a couple pages in Appendix A

11 of this report. And why that wasn't put into the

12 introduction of the other, I, it's a real mystery.

13 DR. WALLIS: And the same thing is true of

14 OSU work. I mean OSU has been working for two or

15 three years on downcomer mixing and I don't think

16 we've yet seen the final reports, so we don't really

17 know the conclusions and the evidence.

18 And yet it is very important to this PTS

19 work, it doesn't appear at all in this NUREG.

20 MR. BESSETTE: Yeah, well, it's a draft.

21 DR. WALLIS: So what do we conclude? That

22 it wasn't, I don't know what to conclude.

23 MR. BESSETTE: The December NUREG is, of

24 course, it's a draft and it still needs a little work.

25 DR. WALLIS: Well, are you now going to

1 put in a summary of the OSU work and it's conclusions
2 and supply some evidence?
3 MR. BESSETTE: Yes.
4 DR. RANSOM: Well, are there results from
5 that work that would change any of the conclusions, I
6 guess, that are in this NUREG?
7 MR. BESSETTE: No, no. I think the,
8 certainly the results of the OSU report are implicit
9 in the NUREG.
10 DR. WALLIS: Either that or someone
11 decided to ignore them.
12 DR. KRESS: Well, that work, as I
13 remember, was taken just to confirm your assumption on
14 the mixing. And pretty much did confirm it.
15 MR. BESSETTE: There was a couple of
16 points to it. This one was to investigate phenomenon,
17 mixing phenomenon. Second was to perform integral
18 system experiments of PTS type thermal hydraulic
19 transients to produce data.
20 It was something, you know, in previous,
21 all the previous experimental programs we've had that
22 the emphasis has been on core, ultimately on does the
23 coring cover peak clad temperature and things like
24 that.
25 It's the first time we tried to focus on

1 the, our emphasis on downcomer characteristics. So
2 that was the second main purpose of the OSU testing
3 program, and it also, in producing this integral
4 system data to provide some assessment data base
5 specific to PTS for the computer codes, RELAP.
6 DR. KIRK: Without this, the briefing will
7 end early. I have one of those five hour batteries
8 that lasts for approximately two and a half. Not the
9 quite the length for a transcontinental flight.
10 What slide are we on, Ed?
11 MR. HACKETT: Three, actually four. While
12 Mark is still setting up, just to go through, I guess
13 the Committee would have the draft NUREG by now.
14 DR. KIRK: One also begins to appreciate
15 some of the advantages of so-called old technology.
16 Okay, again I apologize for my lateness.
17 The objectives of the meeting are to
18 review the draft NUREG that was issued at the end of
19 last year from researched NRR. Detailed and technical
20 basis that we've outlined in that NUREG that we
21 believe provides a strong case to support rule making.
22 Discuss our ongoing activities, both in
23 research and in NRR. Address concerns that you
24 previously raised, and Ed is it correct to say that we
25 are requesting a letter?

1 MR. HACKETT: That's correct.

2 DR. KIRK: Okay. We'll start at the end,
3 so in case there's a fire drill, you know where we're
4 going. And we will be working towards this at the end
5 of the day. As a result of the, I guess it's about
6 been three years of very concerted effort on the PTS
7 re-evaluation, we believe we've provided the technical
8 basis to recommend revision of the PTS Rule, mainly 10
9 CFR 50.61.

10 Two points to bring out from the work are
11 that in plant-specific evaluations of two of the most
12 embrittled plants in the fleet, including two of the
13 most embrittled plants in the fleet, we find that we
14 have through-wall cracking frequency at or below five
15 times ten to the minus eight at the end of what would
16 be currently anticipated as the license extension.

17 Another way to look at the current result
18 is we examined what the through-wall cracking
19 frequency is at our current $RT_{PTS}$ screening limits and
20 that works out to something on the order of one times
21 ten to the minus eight.

22 And that can be compared with what we
23 thought we'd been accepting, which is five times ten
24 to the minus six. Obviously the plants are a lot
25 safer than we previously believed them to be.

1 DR. WALLIS: Mark, in your figure 1.1,
2 that's a plot of frequency versus surface temperature.
3 And it says that 270 $RT_{NDT}$, which is a present
4 screening criterion, the frequency is ten to the minus
5 four.
6 DR. KIRK: That, yeah, I apologize for
7 that graph. That's a misinterpretation of that plot.
8 And what we should not have done, as you see the graph
9 on the screen, is we shouldn't have put the two sigma
10 margin on there.
11 Because once one adds the two sigma
12 margin, then you have to change the X axis from being
13 a mean to a mean plus two sigma. So the --
14 DR. WALLIS: It still seems the wrong way.
15 I mean if it should be screened at two, now why should
16 you allow people to go to 270?
17 DR. KIRK: Well, it's really adding
18 something to the screening criteria and then also
19 adding something to the way that it's evaluated.
20 DR. WALLIS: You add the same thing to
21 both?
22 DR. KIRK: You basically add the same
23 thing to both.
24 DR. WALLIS: It's extraordinarily
25 confusing.

1 DR. KIRK: I would concur.

2 MR. MAYFIELD: This Mike Mayfield. Let's,
3 we need to back up and provide a little history. When
4 we did the original PTS Rule, there was a concern, as
5 was noted.

6 The calculations were done based on mean
7 surface temperature. And the intent was to then use
8 that mean value as the point of comparison. However,
9 the embrittlement correlations that were used, in
10 Regulatory Guide 1.99, included a two sigma margin.

11 And there was some considerable interest,
12 and at that point was viewed as a persuasive interest,
13 to use the same embrittlement correlation methodology
14 that people used when they were looking at setting
15 their pressure temperature limits.

16 So that you didn't have two different
17 schemes, two different methodologies that people had
18 to make use of. So they took the 60 degree margin
19 that was in Reg Guide 1.99, and they added it to the
20 210 degree mean value.

21 And said now we'll use that as the point
22 of comparison. So there's one methodology for
23 calculating embrittlement. So that was the history
24 behind it. It's not that we're actually allowing
25 people to run to a more embrittled state than

1 reflected by the --

2 DR. WALLIS: That's the way it simple

3 appears. I mean even if this figure, you can see 270,

4 ten to the minus four.

5 MR. MAYFIELD: Well, we wouldn't allow

6 anyone to go to 270 as a mean value, sir.

7 DR. WALLIS: I know, I don't care what you

8 would allow. I mean the figure says it. So something

9 --

10 MR. MAYFIELD: The figure does not say it,

11 sir. The figure says we would, that on a mean surface

12 temperature, not the, not the way we would calculate

13 $RT_{NDT}$.

14 DR. WALLIS: But that's the problem is

15 your RT, there is so many different $RT_{NDT}$'s that the

16 reader can't figure out which one you're using.

17 DR. SHACK: If you look at their Figure

18 6.1, they plotted that graph the way they should have

19 plotted this one with RT --

20 DR. WALLIS: I don't care about that. So,

21 are you going to clear this off. Because --

22 DR. SHACK: Reg Guide 1.99 is the X axis.

23 DR. KIRK: Certainly one of the aims of

24 the project and one of my personal aims is to make it

25 a lot less confusing this time through.

1 DR. WALLIS: Because it looks to me as if
2 you've gained a factor of ten to the fourth, by
3 comparing this with what you're saying today. And
4 that is an extraordinary achievement.
5 DR. KIRK: I guess I'll say one of our --
6 MR. MAYFIELD: I'm sorry, I can't, I can't
7 let that go unrefuted. We do not allow plants to
8 operate at that level on a mean surface temperature.
9 I simply can't allow that to stand.
10 DR. WALLIS: What do you mean by mean
11 surface temperature?
12 MR. MAYFIELD: It's the mean value of the
13 surface embrittlement. The embrittlement at the
14 vessel surface, as characterized by the reference nil
15 ductility.
16 DR. WALLIS: Are there other places where
17 it's higher?
18 MR. MAYFIELD: No, sir.
19 DR. WALLIS: Well, if it's the mean, there
20 must be other places where it's higher and lower?
21 MR. MAYFIELD: Well, there is, if you went
22 all the way around the surface you would find a
23 variation in embrittlement. So, certainly, there will
24 be places that it's higher. But there's no place that
25 it goes up to a mean value of 270 degrees.

1 DR. WALLIS: So when you rewrite this
2 report you will make it really clear which $RT_{NDT}$ you're
3 talking about and which T you're talking about,
4 because there are all kinds of different temperatures.
5 MR. MAYFIELD: Yes.
6 DR. WALLIS: When you plot T minus $RT_{NDT}$,
7 the reader has, this reader has a tremendously
8 difficult time figuring out which one of the two
9 you're talking about. Because there are different ways
10 of defining both of them.
11 MR. HACKETT: There's that, I think it's
12 obvious there's a fair bit of confusion over this
13 issue and has been over the years. What one of our
14 goals today will be to try to clarify, we'll try. We
15 see how well we do by the end of the day.
16 DR. WALLIS: That's why you need a Peer
17 Review.
18 MR. HACKETT: Well, that's at least one of
19 the reasons. I would say there are many reasons. And
20 one of the things that I was going to say, while we're
21 on the subject, Mark will introduce this.
22 But, not to, you know, intentionally add
23 further confusion, but we are introducing the concept
24 of a weighted $RT_{NDT}$ in this report, as you've probably
25 seen. So it will shift yet again.

1 But we'll try to define that as best we can.

2 DR. KIRK: Which would perhaps be a

3 conversation better left until later. But suffice it

4 to say, when you get through all the analysis,

5 obviously the first main bullet makes the point that

6 doing a much more thorough analysis of PTS risk at our

7 currently operating plants we find that the risk is

8 much, much lower.

9 DR. WALLIS: I'm going to jump in again.

10 When you write your overview in your introduction, it

11 would help a great deal if you would explain how you

12 managed to do this.

13 Now, when I read about floors, I flaws, I

14 find very different assumptions about flaws that you

15 made before. And it says in your report that you used

16 a factor of 20 or 70. Well if it gains you 70, that's

17 most of your factor of 100 that you've gained.

18 And it means that all of this, maybe for

19 the thermal hydraulics you gain a factor of 1.2 or

20 something, but what you assume about flaws is

21 extraordinarily important in reaching this conclusion.

22 DR. KIRK: Yes, certainly it is.

23 DR. WALLIS: And then moving around the

24 $RT_{NDT}$ to be a best estimate rather than limiting and

25 doing statistics on it and so on, probably gains you

1 a factor of five or something, at most.

2 So it would clear if you could spell out

3 what are the contributors to this change. And what

4 confidence you have in the various elements in it.

5 DR. KIRK: We'll be going into that in

6 detail today.

7 DR. WALLIS: Thank you.

8 DR. KIRK: And then the point of the

9 second bullet is that as a consequence of the fact

10 that the analysis suggests that the plants are much

11 safer than we believe them to be, one could use this

12 as a justification for a significant increase in the

13 PTS screening criteria to put it on roughly the same

14 basis as we currently use the $RT_{PTS}$ metric.

15 The limit would be increasing by something

16 between 80 and 110 degrees Fahrenheit, relative to the

17 screening limits that are in 10 CFR 50.61. We should

18 point out, although I think it's already become quite

19 clear that this project is not yet over.

20 We both, ourselves and research, and our

21 colleagues at NRR have several ongoing activities in

22 research. We're completing our analysis of Calvert

23 Cliffs Plant. We're looking into our current results

24 in a lot more detail than we were able to do in the

25 report that you have on your desks.

1 And looking at the steps we need to take
2 to generalize these results to all of the operating
3 PWRs. We're conducting a V&V of FAVOR. This, again,
4 has already been discussed. We're convening an
5 external Peer Review Panel to go over the project.
6 And we're also looking at the implications
7 of these results on the operating limits, as spelled
8 out in 10 CFR, Appendix G. We'll discuss that in a
9 little bit greater detail later. But, suffice it to
10 say, that having removed the conservatisms from the
11 materials limits on an accident, we find now that the
12 conservatism varied in Appendix G.
13 For example, the assumption of a quarter
14 T flaw, ten percent safety factor on pressure would
15 make the operational limits, in fact, more limiting
16 than the accident limit. So there's something that
17 needs to change there to.
18 At NRR, again, we of course passed them
19 the NUREG on 12-31-02. They promised us comments back
20 by the end of March and of course NRR management needs
21 to make a decision as to whether or not it wishes to
22 proceed with rule making.
23 DR. FORD: Mark, presumably, given the
24 difference in timing there, that you haven't finished
25 all the RES work, as given by the top bullet, is there

1 enough flexibility in the system that you can take
2 into account any modifications to the conclusions in
3 the current NUREG document. Is that correct?
4 DR. KIRK: I believe so. I mean there is
5 no, at this point, formal management commitment to
6 proceed. However, discussions among the staff of RES
7 and the staff of NRR, there's at least a working level
8 understanding that their work could proceed in
9 parallel with our finishing work, without tripping
10 things up too much.
11 DR. FORD: The reason why I bring it up
12 is, as you know, in license renewal discussions that
13 we have with lots of plants, there are several plants
14 approaching the 270 limit already.
15 DR. KIRK: Right.
16 DR. FORD: And we always question them
17 about pencil sharpening and all this and what's the
18 rationale behind that. And you get the feeling that
19 everyone is saying, ah, but don't worry, this thing is
20 going to solve it all. And we want to be sure this is
21 on sound basis before we --
22 DR. KIRK: Yes, yes, exactly. And I think
23 the, there is, of course, is this, you can see, if you
24 turn around in the back of the room, there is of
25 course a great interest in this result on the part of

1 the industry.

2 However, from attending public ASTM

3 meetings, I'm also aware that they're certainly not,

4 and they can speak for themselves, but it's not my

5 understanding that they're prepared to wait on this.

6 Certainly if plants are approaching 270 or

7 300 and they need to make business decisions to

8 proceed, one could logically expect the business

9 operators to pursue other alternatives.

10 MR. ROSEN: I'm interested in the last

11 bullet on the slide, the decision to proceed with rule

12 making. Will this depend on the weather or perhaps

13 how one feels when they get up on a particular

14 morning? I mean are there any criteria?

15 MR. HACKETT: Dr. Rosen, it is probably

16 going to come down to, largely, a resource decision.

17 We did, in addition to sending the paper to NRR, it

18 was briefed through the Executive Director for

19 Operations actually also just this week.

20 I think everyone things, technically,

21 there is a rigorous basis that's been established to

22 move ahead with this. It's probably going to boil

23 down to, from the perspective, not for me to speak for

24 NRR, but, you know, looking at from the Director of

25 NRR's perspective, this would go into the bin with a

1 lot of other things that NRR is pursuing.

2 And they are going to have to look at

3 allocation of resources for, you know, what the

4 Committee knows to be a two to three year process, at

5 least, to go forward with this. So, I think that's

6 the type of thing it will boil down to.

7 Where this ends up in NRR's prioritization

8 scheme. And as Mark indicated, a lot of that depends

9 on the interest of the utilities and the affected

10 utilities. You know, discussing that or looking at,

11 I think, I wasn't at the meeting, but there was some

12 discussion, I heard, of potential for direct final

13 rule making on this type of thing.

14 Which could be, or a petition for rule

15 making that might come from the industry if it doesn't

16 appear that that particular activity is going to get

17 engaged on the, you know, the most optimal schedule.

18 But it's really, I think, what it will

19 boil down to, in my opinion, at least, the resource

20 decision.

21 MR. ROSEN: So, if it's a resource call,

22 then I expect that the resource criteria, how you

23 apply resources, there are criteria. And I would

24 suggest that those are probably associated with the

25 Commission's strategic goals.

1 MR. HACKETT: That's correct.

2 DR. KRESS: With respect to that other,

3 many plants out there now that will be pretty soon

4 approaching the current $RT_{PTS}$ limit?

5 MR. HACKETT: Not soon. And the

6 realization, I guess at this point, is that I suppose,

7 and there are others here that can probably speak to

8 this better than I could. I think the Palisades Plan

9 is still technically the closest.

10 I believe, last I remember, that was 2011.

11 So in terms of, that's close enough, in terms of if

12 you're the Palisades Licensee and you're looking --

13 DR. KRESS: If you want a relicense.

14 MR. HACKETT: If you want to re-license

15 that plant, I'm sure they're looking that far ahead

16 and much further. So obviously the sooner the better

17 with regard to this type of activity.

18 Even if this activity is going forward and

19 the pace is not quite what a particular Licensee would

20 like, that Licensee, of course, does have options to

21 pursue that individually with NRR.

22 I think it would be, obviously, more

23 desirable to have this thing, you know, further along,

24 but that opportunity exists too.

25 DR. BONACA: At some point, one of the

1 major contributors, it seems to me, as we discussed in
2 the previous presentation, is the elimination of
3 secondary side cool downs as likely contributors.
4 And that really is because of confidence
5 that you have in operator action. Now, during, you
6 know, when I was reviewing the material I was trying
7 to see a correlation between that assumption, which is
8 so fundamental, and the precursors that you have on
9 Figure 1.2.
10 At some point during your presentation I
11 would like you to make some connection to that and
12 tell me if anyone of those, because I didn't go back
13 to the material and review it, was in fact a secondary
14 side cool down.
15 And why should we have confidence that if
16 any one of those were in fact secondary side cool
17 downs they would not occur again.
18 DR. KIRK: In fact, and we'll get to this
19 as we get into the detailed discussion, but the reason
20 why secondary side cool downs have not shown up as
21 being nearly as important as they were previously, is
22 attributable to three reasons.
23 One of them being credit for operator
24 action, however that's the ugly stepsister of the
25 three reasons. That's the least important factor.

1 So, we'll, but I'll save that for later.

2 DR. BONACA: Yeah, I just, I was trying to

3 understand, you know, reviewing the materials, Figure

4 1.2, how does it apply to the three reasons here, and

5 realizing that there is no discussion of that

6 anywhere.

7 DR. WALLIS: But if you're on Figure 1.2,

8 I think you ought to explain what it has to do with

9 PTS. Because there's no bridge between that and the

10 rest of the analysis. And if you'd indicate what kind

11 of challenges in terms of Ks were involved or

12 something, that would be related to the other curves

13 in the introduction.

14 But Figure 1.2 is just an indication that

15 there have been transients with certain DT by DTs, and

16 the reader doesn't know what this means in terms of

17 its relationship to any criteria or anything.

18 DR. KIRK: Well, we can certainly make

19 that connection.

20 DR. WALLIS: When you're talking about

21 operator action, I notice that in your report that you

22 stated that there had been a rigorous PRA analysis of

23 operator action and rigorous PRA treatment of operator

24 -- I'm not sure there is such a thing as a rigorous

25 PRA treatment of operator action.

1 (Laughter.)

2 DR. KIRK: Alan, is that a rhetorical

3 question or do you want to try it?

4 MR. KOLACZKOWSKI: Let's just say we'll

5 address --

6 DR. WALLIS: It's a statement in your

7 report.

8 MR. KOLACZKOWSKI: I understand. We'll

9 address that at the appropriate point. And then the

10 Committee can decide whether they think it was

11 rigorous enough. How's that?

12 (Laughter.)

13 DR. SHACK: One of the other things, Mark,

14 you know, everything deals with essentially the

15 fabrication flaws and there's no statement about flaw

16 growth in an even bounding sense.

17 It would seem to be, especially as I'm

18 projecting lives out to 400 years to say something

19 about the possibility of flaw growth.

20 DR. KIRK: Okay.

21 MR. MAYFIELD: This is Mayfield. Just to,

22 that has been looked at, and it's certainly something

23 we should have picked up in the report. I agree. And

24 it's something we will put in.

25 DR. SHACK: Yeah, I don't think it's a

1 show stopper, but it's certainly something --

2 MR. MAYFIELD: Yeah, those kinds of

3 calculations have been done in the past and for the

4 size flaws you're talking about here and the range in

5 stresses that the vessel sees, where you would get

6 operation, you're going to operate a very long time

7 before you'll substantively modify that flaw

8 distribution.

9 DR. SHACK: At least based on

10 embrittlement I can now operate a very long time.

11 MR. MAYFIELD: It's something we need to

12 address in the report and will do so.

13 DR. KIRK: Okay, so in terms of the way

14 this has been laid out, we're going to give some

15 background on the current implementation of the PTS

16 Rule. Although based on the comments that I've

17 already received, I'm feeling that that background is

18 inadequate, but we'll give it a shot.

19 And talk about the motivations for why we

20 undertook this project in the first place. And then

21 we'll go into what is essentially a verbal

22 walk-through of the NUREG that you've been given.

23 Discuss the scope of the analysis, the

24 plant-specific results. Talk about the reactor vessel

25 failure frequency acceptance criteria, and discuss our

1 conclusions regarding a proposed new PTS screening
2 limit.
3 Oops, I'm going the wrong way. So for
4 background, here's a graph I've truly come to despise,
5 and it wasn't just recently. I would whole-heartedly
6 agree with Dr. Wallis that $RT_{NDT}$ is confusing.
7 And we can certainly take steps to try to
8 alleviate that problem. But the graph, for what it's
9 worth, is indeed the basis of the current screening
10 criteria. The PRA calculations established a link
11 between a mean surface $RT_{NDT}$ meaning an $RT_{NDT}$ accounting
12 for the effects of embrittlement evaluated on the
13 inner diameter of the vessel, using the peak fluence
14 anywhere in the vessel.
15 And the PRA calculations establish a
16 relationship between that, and at 210 degrees, a
17 yearly through-wall cracking frequency of five times
18 ten to the minus six. For reasons that Mike has
19 already tried to explain and are probably too
20 difficult to go into more detail on, a margin of 260
21 degrees was added to that and roughly -- 60, sorry.
22 Ah, 260, 60. Sixty degrees Fahrenheit was
23 added to that and essentially that same margin is
24 added in the assessment process. So while it is
25 indeed confusing, it is also, in fact a wash.

1 DR. WALLIS: Which is the real, it's the
2 $RT_{NDT}$ that you talk about as being 270, really 210 plus
3 a 60 degree --
4 DR. KIRK: That is correct.
5 DR. WALLIS: -- artificial addition? And
6 is the $RT_{NDT}$ you are talking about today, as a result
7 of your far better analysis, is it plus 60 degrees or
8 is it a real $RT_{NDT}$ --
9 DR. KIRK: Absolutely not. It's a real
10 $RT_{NDT}$.
11 DR. WALLIS: So I couldn't take this curve
12 and superimpose it on your curve in your Chapter 4 or
13 something where you show exactly the same thing with
14 numbers like ten to the minus nine and ten to the
15 minus four? I can't do that?
16 DR. KIRK: I, I, no, it would something
17 akin to plotting a fruit bowl.
18 DR. WALLIS: Well, I think that's going to
19 be very clear.
20 DR. KIRK: I agree, I agree. That point
21 is well taken.
22 DR. SHACK: This, I mean, I always think
23 of them in terms of real $RT_{NDT}$ and regulatory $RT_{NDT}$.
24 You know, there's the one I calculate out of Reg Guide
25 1.99 Rev. 2, and then there's the real world.

1 These are the real world numbers. The
2 ones you are plotting in Chapter 4 are the real world
3 numbers, too.
4 DR. KIRK: That's correct. And what
5 we've, by going through the PRA frame work and the
6 uncertainty analysis we have, again, like I said, one
7 of the expressed aims of this project is to try to do
8 this quote/unquote right and to get rid of a need for
9 the very confusing margins.
10 DR. SHACK: When you get, the 60 degrees
11 just relates the $RT_{NDT}$ to the regulatory $RT_{NDT}$.
12 DR. WALLIS: But when you get to Appendix
13 A, you begin to feel this is the real world. But
14 there are other, the regulatory world is a sort of
15 Alice in Wonderland world. Where you think you've got
16 something, but it isn't that, it's something else
17 defined some other way.
18 Let's get rid of all that in the future.
19 DR. KIRK: Works for me. So in the
20 current rule, if anybody's regulatory $RT_{NDT}$, to borrow
21 Dr. Shack's term, which I really like. If the
22 regulatory $RT_{NDT}$ is, seemed to approach the regulatory
23 limit of 270 degrees Fahrenheit for axial welds,
24 plates or forgings, or 300 degrees Fahrenheit for
25 circumferential weld, the Licensee has to do

1 something.

2 They either have to implement flux

3 reduction, which decreases the efficiency of their

4 plant but protects the beltline material from

5 embrittling quite so fast. Or they need to perform a

6 plant-specific PRA according to Reg Guide 1.154 to try

7 to justify to NRR why operation in excess of

8 regulatory limit is in fact a wise thing to do.

9 I've got three slides on motivations for

10 revision. The words in the yellow box probably say

11 far more than all the details I've put on this slide.

12 Yankee Rowe in the early, or I should say late 1980's,

13 found that it was approaching the regulatory limit at

14 its anticipated EOL.

15 The Yankee Atomic Energy Company attempted

16 to follow the provisions of Reg Guide 1.154 to build

17 a case for operation. In excess of the limit, again,

18 this is indeed a very long story which I think the

19 Committee is probably, in general, more familiar than

20 me.

21 Suffice it to say it didn't turn out so

22 well, and the operating company made the business

23 decision to shut down the plant in September of 1991.

24 As a consequence of this, our Commission directed the

25 staff to look into work necessary to revise the

1 technical basis for both the regulatory guide and the
2 associated rule.
3 You've seen this slide before. One of the
4 things that the staff thought about, having gotten
5 that directive is, gee, there are a lot of technical
6 improvements that have been made in the past 20 years
7 that suggests that the current rule is, indeed,
8 conservative.
9 These improvements occur across the three
10 major technical areas. Those being PRA, Thermal
11 Hydraulics and Probabilistic Fracture Mechanics.
12 We've gone through this slide before, but suffice it
13 to say when one thinks and compares the type of
14 analyses, the type of data and those sorts of things
15 that were used in the original analysis and compares
16 it with what we would do today, you indeed find things
17 that would both reduce, you would believe if you did
18 it right or to the best of your ability today, would
19 reduce the calculated risk.
20 Those being represented by the green
21 downward arrows. And indeed you'd find that there are
22 some things that you feel you should include today
23 that would in fact increase the risk, as represented
24 by the red upward arrows.
25 Taking an example from PRA, previous

1 external precursor events were not considered. Mainly
2 because the calculated probabilities of, yearly
3 probabilities of vessel failure in the previous
4 analysis in the minus six range when compared with
5 what a scoping analysis would tell you would be an
6 external event frequency.
7 You decide that the external event
8 frequency is contributing at least two orders of
9 magnitude less and so why bother including it.
10 However, our numbers being, having a starting point of
11 two orders of magnitude less, there's a necessity to
12 look at external events and other things.
13 Having gone through these analyses, we're
14 now in a position to put sizes to some of these
15 arrows. Certainly some of these things matter more
16 than others, but what we've tried to do, to the
17 greatest extent practicable, is to take an even
18 approach to this and include everything that we
19 possibly could within, you know, within the necessary
20 scope and resources.
21 This was brought up earlier, with Dr.
22 Kress' question. Certainly some plants are close to
23 the current screening criteria. This is a plot of how
24 many degrees Fahrenheit the regulatory $RT_{NDT}$ values are
25 from the current regulatory limits, plotted versus the

1 time that the plants come to end of license.

2 Certainly anybody that's close, within the

3 red zone, and that's not an official term, the

4 operator would worry that some change to their

5 measured chemistry value, the next surveillance

6 capsule, an alteration in their fluence calculation or

7 methodology could take them from being slightly under

8 the line to slightly over the line.

9 So anybody that gets anywhere close to the

10 current regulatory limits is doing something to make

11 sure that they stay away from them.

12 DR. WALLIS: Excuse me, you referenced

13 chemistry. Is the chemistry of the water figured into

14 this possibility of surface flaw development?

15 DR. KIRK: No.

16 DR. WALLIS: It's not?

17 DR. KIRK: No. There are people here that

18 know a lot more about that than I, but I don't think

19 that's a major factor.

20 MR. HACKETT: That gets back to Dr.

21 Shack's previous question on, you know, whether or not

22 there is potential for any type of flaw growth.

23 Which, you know, over a very long period of time it

24 would be prudent for us to go back and take a look.

25 You know, heretofore, has not proven to be

1 an issue. But, no, other than that, that would be the
2 only way the water chemistry would factor into it.
3 DR. WALLIS: So it's not figured into your
4 analysis at all?
5 MR. HACKETT: No, it's not.
6 DR. FORD: You know, I agree with your
7 assessment. I honestly don't see right now how
8 environmental degradation in these particular plants
9 could impact this over a reasonable time period. But
10 what if you were wrong?
11 I mean so many times, I mean we've just
12 seen this the other day. We've got a model
13 uncertainty, a system model uncertainty. What would
14 happen if? So, for instance, would your model be able
15 to say, if I had a surface flaw, for whatever reasons,
16 of say a quarter of an inch.
17 And we don't know how it got there, but it
18 got there. How would that impact the results?
19 DR. KRESS: The standard answer to that is
20 we use defense-in-depth, which involves the balance
21 between CDF and containment failure. And they have a
22 containment failure now calculated.
23 And it looks to me like it's sufficient
24 defense-in-depth to deal with uncertainties like that.
25 Which is something I see was lacking in the past in

1 this area.

2 DR. FORD: My specific question to him

3 was, how do you take into account that methodology?

4 MR. HACKETT: I guess there are a couple

5 of ways that you could come at that. One is that you

6 could say the fabrication flaw, density and

7 distribution brackets that to some degree now.

8 Either analytically or experimentally we

9 have seen flaws in that range. And the experimental

10 part has shown that there is a lot of small flaws that

11 are virtually inconsequential when it comes to PTS.

12 But they do, when you go beyond that and

13 you're trying to address this analytically with codes

14 like PRODIGAL, or you're just making, you know,

15 statistical estimations of what might be there, those

16 type of things do get factored in where you have maybe

17 a quarter of an inch flaw or even a half an inch flaw

18 that's going to show up there with some statistical

19 distribution.

20 So to that extent, it's covered, but it's

21 not assumed to have gotten there by any type of flaw

22 growth mechanism. At least the Deputy Office Director

23 for Research, Jack Strosnider, has asked us as part of

24 one of our sensitivity studies, at least to address

25 that type of thing.

1 Not specifically the flaw growth. Almost
2 sort of regardless of how a flaw might get there, ask
3 the question that Dr. Ford just asked. What if you
4 missed it? You know, what if there is something you
5 just miss?
6 Like analogous to the Davis-Besse
7 situation. Previous to that we weren't anticipating
8 you'd see degradation of that magnitude. So that
9 potential always exists and we were going to try and
10 come at it in this project through some sensitivity
11 studies that, in that case, have yet to be performed.
12 DR. FORD: I was about to ask, when will
13 that be done?
14 DR. KIRK: That was on the ongoing work
15 slide.
16 DR. FORD: Oh, okay, I didn't see it.
17 DR. KRESS: With respect to this slide
18 here, I'm sure it's plant-specific, but the question
19 I have is is there a reasonable rule-of-thumb that I
20 could use that says if I'm, say, 50 degrees or so many
21 degrees away from the limit, how many years I have
22 left?
23 DR. KIRK: About a degree Fahrenheit per
24 year of operation. Once you're, with the proviso,
25 once you're on the flat part of the embrittlement

1 curve, which if you're close to the limit, you
2 probably are about a degree Fahrenheit per year.
3 Between a degree Fahrenheit and degree
4 centigrade per year to put an uncertainty bound on it.
5 DR. KRESS: Thank you.
6 DR. KIRK: Which is why a few degrees
7 seems to be fought over so hotly, because it has very
8 real economic impacts. So the scope of our analysis
9 which, again, I believe the Committee is familiar
10 with.
11 We selected four plants for very detailed,
12 dare I say, PRA analysis. We've included one plant
13 from each of the major PWR Manufacturers. Two plants
14 were plants that were included in the study that
15 established the current PTS Rule.
16 Those being Calvert Cliffs and Oconee.
17 The other two plants in our study, Beaver Valley and
18 Palisades, are two plants that are among the closest
19 to the current PTS screening criteria, if not the
20 closest.
21 MR. HACKETT: Let me add the caveat there,
22 especially for the record, that that means close at
23 EOL, not close right now.
24 DR. KIRK: Yes, yes, yeah. And there is
25 a correction I failed to make. The word all should,

1 of course, be in quotes because complete knowledge is,
2 of course, never attainable.
3 MR. ROSEN: When you say close at EOL, for
4 those plants, close at end of life of their current
5 license life which is 40 years?
6 DR. KIRK: That's correct, that's correct.
7 Both Beaver Valley and Palisades are within a degree
8 Fahrenheit of the current screening limits at end of
9 40 years. And the last bullet just simply reflects
10 the fact that we believe, and it remains for others,
11 of course, to pass judgment, that the quality and the
12 detail of the plant-specific analysis is indeed very
13 comprehensive.
14 We'll go into a few details of the
15 analysis approach. Our approach has been briefed to
16 the Committee before in even greater detail, so we
17 just wanted to hit the high points here.
18 The approach includes two main components,
19 the first being plant through-wall crack frequency
20 estimates. In constructing these estimates, we've
21 used a frame work that was laid out by Nathan several
22 years ago.
23 And it's important to point out that
24 overlaid on this entire process we've addressed and
25 quantified uncertainties as an integral part of the

1 analysis process. That's quite a radical and I would
2 personally say good departure from the past where
3 uncertainties were buried with implicit conservatisms
4 and were handled fairly non-uniformly without.
5 Here we tried to do a much better
6 front-end job. The way the analysis process works,
7 and of course there's many, many levels of detail
8 below this which we won't touch on today.
9 But one starts with an events sequence
10 analysis. That defines both the combination of things
11 that can go wrong and the frequency with which they go
12 wrong. The combination of things that go wrong are
13 then fed into a thermal hydraulic analysis, conducted
14 using the RELAP Code.
15 That estimates the temporal variation of
16 pressure, temperature and heat transfer coefficient,
17 which is fed through a probabilistic fracture
18 mechanics analysis based on linear elastic fracture
19 mechanics techniques performed using the FAVOR Code.
20 That combined with material property and
21 prevention of embrittlement information, flaw
22 information and fluence information, allows us to
23 calculate the conditional probability with which a
24 through-wall crack will occur.
25 That's conditioned, of course, on the fact

1 that the sequence has occurred, so those conditional
2 probabilities are multiplied by the sequence
3 frequencies to obtain an estimate of the yearly
4 through-wall cracking frequency.
5 DR. WALLIS: May I ask you how you handled
6 uncertainties? Now in the PFM analysis in this NUREG
7 we looked at, there's quite a long discussion of
8 epistemic uncertainty, aleatory so how you handle that
9 with PFM.
10 And it wasn't clear to me how you handle
11 thermal hydraulics. Do you have a thermal hydraulic
12 scenario? And then for that scenario you then do
13 these uncertainties on PFM? Or do you have a the
14 thermal hydraulic uncertainties also propagating
15 through the PFM uncertainties? How do you handle
16 that?
17 DR. KIRK: The, once the thermal
18 hydraulic, once the pressure temperature and heat
19 transfer coefficient variation with time gets to the
20 PFM analysis, the PFM analysis treats it
21 deterministically.
22 DR. WALLIS: It does? Okay.
23 DR. KIRK: Yes, that's correct. The
24 uncertainty treatment on thermal hydraulics is
25 effectively dealt with before that. And to give you

1 the details I'd have to defer to either David or Alan.
2 DR. WALLIS: Okay, so it gets
3 deterministic once it gets --
4 DR. KIRK: Once it gets to PFM it's
5 deterministic, that's right.
6 DR. RANSOM: Mark, one question on the
7 FAVOR Code. The second report indicates the FAVOR
8 Code can't be used. And yet in this one says the
9 FAVOR Code is a part of the analysis. So I'm
10 wondering what is the status of that?
11 DR. KIRK: I'm confused. What's the
12 second report?
13 DR. RANSOM: The second report is from
14 University of Maryland by Chang, Alemenas and Mosleh.
15 MR. BESSETTE: I think that's in a time
16 sequence. When we, two years, one year ago when we
17 were doing a lot of the early uncertainty evaluation,
18 TH uncertainty evaluation, the FAVOR Code wasn't final
19 yet.
20 So a lot of that work was done prior to
21 the release of FAVOR.
22 DR. RANSOM: Okay, this is a year old, I
23 guess. Was that ever released or was it just a report
24 to the NRC?
25 MR. BESSETTE: It's, well it's been in the

1 works for about two years. The actual draft report --

2 DR. RANSOM: Okay, well FAVOR is working?

3 DR. KIRK: Yes. If FAVOR wasn't working,

4 I wouldn't be sitting here.

5 DR. WALLIS: FAVOR sounds great, actually,

6 from your, the NUREG that we reviewed.

7 DR. KIRK: FAVOR sounds great. Is that on

8 the record?

9 DR. WALLIS: But we don't have, well, it

10 sounds great, but we don't have, you need to fiddle

11 the bass a little bit. There is this big whole about

12 thermal hydraulic uncertainty which is not treated in

13 this NUREG.

14 And then we get given these other reports,

15 you know, uncertain age, and we don't quite know what

16 to make of them. Are you going to put a proper

17 treatment of thermal hydraulic uncertainty and then

18 revise NUREG?

19 DR. KIRK: Yes.

20 DR. WALLIS: Okay, thank you.

21 DR. KIRK: Okay, so once you've figured

22 out how often you think you're going to get a

23 through-wall crack in your plant per year, you need to

24 compare that with some metric of how frequently you

25 would find that okay.

1 So we developed an acceptance criteria for
2 through-wall cracking frequency consistent with
3 current NRC policy and Commission guidance,
4 specifically as expressed in Reg Guide 1.174.
5 And taking due account of the comments
6 from this Committee and other areas, and Nathan will
7 be discussing that in much greater detail later as we
8 will be discussing the plant through-wall cracking
9 frequency estimates.
10 And just notionally you can think of
11 combining those two figures as shown on the lower
12 graph computing through-wall cracking frequencies for
13 different plant ages, and then using those data to
14 discern a new screening limit.
15 And we can say upfront that we didn't go
16 in with the a priori assumption that we would be using
17 $RT_{NDT}$, it turns out that that looks like a reasonable
18 thing to do. But that's certainly not the only way to
19 do it.
20 So what we'll do now is go into some more
21 details of each of the major parts of the analysis.
22 DR. WALLIS: Could you have used
23 consistent acronyms throughout, so that when, the
24 output of this box is $RT_{NDT}$ or some, TW, no, it's TWC,
25 FTWC or something?

1 DR. KIRK: Of what box, I'm sorry?

2 DR. WALLIS: The output of this whole

3 thing on the left, the frequency of through-wall

4 cracking?

5 DR. KIRK: Yes, yes.

6 DR. WALLIS: There's an acronym somewhere

7 later in the report, although this part of the report

8 talks about the CP. Are you going to make it clear

9 which is the output of this process here?

10 MR. HACKETT: I think what we'll come to

11 is, what you're looking at is what we're calling later

12 on as RVFF, Reactor Vessel Failure Frequency.

13 DR. WALLIS: They are different things.

14 MR. HACKETT: You're right.

15 DR. WALLIS: Are you going to make it

16 clear which is which and how they fit in and how they

17 link to each other and so on?

18 MR. HACKETT: Yes, at least hopefully.

19 DR. WALLIS: Okay.

20 DR. FORD: Mark, could I just ask, since

21 this is approaching the end, just to look further

22 forward. The acceptance criteria, once it is decided

23 upon, will be an absolute value. The other, the

24 plant, will be plant-specific.

25 In the early round you talked about Yankee

1 Rowe being shut down because they couldn't use,
2 couldn't usefully use the existing Reg Guide. Will
3 this be user-friendly enough that the Licensees can
4 use?
5 DR. KIRK: I'm not sure I want to speak
6 for the Licensees on that one. But it certainly would
7 be the intent to, you know, express what we've done in
8 a way that people could understand it.
9 However, from a practical standpoint, one
10 would need to ask the question of if we take, okay,
11 right now let's say that we've got a plant within a
12 degree of the screening criteria.
13 If indeed we do raise the screening
14 criteria by something like 90 degrees Fahrenheit, is
15 any plant likely to ever have to do a plant-specific
16 analysis? Probably not.
17 DR. WALLIS: But if they did, would they
18 have to do all the things that you were describing in
19 your NUREG?
20 DR. KIRK: Yes.
21 DR. WALLIS: Well, how would they do that?
22 Would they regenerate all your data and epistemic --
23 DR. KIRK: I think the parts that the
24 plant would have to redo, and I, you know, encourage
25 anyone to chime in with me. Certainly the fracture

1 mechanics part is fairly generic. The material
2 characterization is fairly generic.
3 The plants already have docketed
4 embrittlement values and material composition values,
5 so all that is essentially done. They have some
6 estimates of fluence, so that's already done.
7 The specific parts that they would have to
8 do is the front end. Is the, is the plant-specific
9 PRA which indeed some plants have and some plants
10 don't. And then they'd need to the thermal hydraulic
11 analysis.
12 DR. KRESS: Your curve is based on fluence
13 as it's associated with the four plants you --
14 DR. KIRK: That's correct.
15 DR. KRESS: Now, if a given plant says now
16 I've got a fluence that's considerably lower than
17 that, is there a real simple rule for them to say
18 this, this means I can change my screening criteria by
19 --
20 DR. KIRK: You wouldn't change the
21 screening criteria. You'd simply --
22 DR. KRESS: I mean you'd change their --
23 DR. KIRK: Oh, yes, yes, yeah. The metric
24 we get to in the end, the so-called weighted $RT_{NDT}$ is,
25 it looks a little ugly when you put it on the page,

1 but it's nothing more than a simple algebraic formula.
2 DR. KRESS: It's linear in fluence.
3 DR. KIRK: Yeah, that uses material
4 property information that's available, fluence
5 information that's available and vessel geometric
6 configuration information which is available.
7 DR. KRESS: So that's the reason you use
8 that metric is cause it's relatively easy for the --
9 DR. KIRK: That's right.
10 DR. KRESS: -- utility to just plug in his
11 case and get that number.
12 DR. KIRK: Yeah, that's correct.
13 DR. KRESS: And he doesn't have to go
14 through all this stuff.
15 DR. KIRK: That would be the hope, yes.
16 DR. RANSOM: Incidentally, one thing I
17 don't understand about this. You talk about the nil
18 ductility temperature as an instantaneous value that
19 you don't want to reach, i.e., or the temperature you
20 don't want to go, I guess, below that, you know, in
21 terms of chilling it down.
22 But yet, in terms of thermal stress in a
23 vessel wall, it's clearly a time-dependent function.
24 You know, it depends on the rate of which you achieve
25 these temperatures. How is the rate actually factored

1 into this?

2 DR. KIRK: The rate is factored in the

3 FAVOR Code, if you want to think about it sort of at

4 a very high level, FAVOR is doing two calculations.

5 It's on the one hand calculating the applied driving

6 force to fracture, which is mostly dependent upon the

7 rate of cool down and the pressure.

8 And at the same time it's calculating the

9 resistance of the material to that driving force or to

10 that demand. And that's mostly dependent upon the

11 temperature and the fluence and the embrittlement

12 characteristics and then those two are compared.

13 The, in terms of the screening metric,

14 something we'll get to, and this is sort of stealing

15 a conclusion. In going through these calculations, of

16 course, we've calculated the driving forces resulting

17 from anticipated PTS sequences and put those through

18 the analyses.

19 And what we find out, coming out of all

20 three of these analyses, is that the, the level, even

21 though these are plants made by different

22 manufacturers, different times, if you get into the

23 details, you look at them as being very different.

24 In fact, the level of demand relative to

25 fracture toughness is fairly consistent from

1 plant-to-plant. But, again, we'll go into that later.
2 DR. BANERJEE: I guess the tunnel
3 hydraulic input is taken by the FAVOR Code and made
4 into a stress of some sort?
5 DR. KIRK: That's correct. We take
6 pressure, temperature and heat transfer coefficient
7 all versus time and solve the conduction equation.
8 DR. BANERJEE: Right. Now is this done
9 one dimensionally, multi-dimensionally?
10 DR. KIRK: One dimensionally.
11 DR. BANERJEE: So you don't take account
12 of variations in the temperatures and pressures or
13 whatever?
14 DR. KIRK: No, no. And we've --
15 DR. BANERJEE: And how accurate is that?
16 What's the uncertainty in taking that into account?
17 Not taking the multi-dimensional aspects into account.
18 DR. KIRK: Relative to the fully detailed
19 analysis, at least from a fracture perspective, not
20 much. Because the cracks tend to grow very long
21 before they grow deep. And once you get a crack
22 that's at least six times its depth, you may as well
23 be doing a one dimensional analysis.
24 I know David has done, looked at the 3-D
25 aspects of the thermal hydraulics.

1 MR. BESSETTE: So, yeah, of course that's
2 one of the things --
3 DR. BANERJEE: How have you done that?
4 MR. BESSETTE: That's one of the things we
5 were concerned about from the start, is whether this
6 one dimensional analysis was adequate or not. What we
7 did was a combination of looking at experiments and
8 supplemented by some CFD analysis.
9 So we looked at the, of course that was
10 one of the objectives of running the Oregon State
11 Program was to provide additional integral system data
12 on temperature distribution in a downcomer.
13 That was in the, during the 80's, there
14 was a lot of work done at Creare in Finland and
15 places, like by Theo also looking at downcomer mixing
16 and kind of separate effects, salt water systems.
17 So we still had a concern or I'd say an
18 interest in knowing that this uniform treatment of
19 temperatures was adequate. And so, so like I say, we
20 did additional experiments at Oregon State and CFD
21 analysis.
22 And in addition to looking at other
23 available data, like ROSA, where we do have an
24 instrumented downcomer, and assured ourselves, let's
25 say, that the temperature variations axial

1 circumferential are with, let's say, ten degrees
2 Fahrenheit.
3 DR. WALLIS: This is whereabouts?
4 MR. BESSETTE: In the, let's say, in the
5 downcomer region.
6 DR. WALLIS: How far down the downcomer?
7 I mean it evolves.
8 MR. BESSETTE: So, yeah, so this is, we're
9 particularly interested in the downcomer region
10 adjacent to the core, which is about, the top of the
11 core is about five feet below the cold leg.
12 DR. BANERJEE: Are you going to discuss
13 this uncertainty or is, what's going to happen? I
14 don't see very much on this --
15 DR. WALLIS: There's nothing in this
16 NUREG. It seems to me it ought to be in this NUREG.
17 It's a big part of the whole picture, it ought to be
18 there. Will it be there?
19 MR. BESSETTE: I'll add it.
20 DR. WALLIS: Will it be there? Will this
21 NUREG be twice as fat, or will there be two or three
22 NUREGs or what? You can't have this the final word on
23 PTS without going thoroughly over these things which
24 aren't in there?
25 MR. BESSETTE: I know, well, in the

1 thermal hydraulics area we have four NUREG/CRs that
2 will be issued to support this NUREG.
3 DR. WALLIS: Well, they will be. But we
4 can't sort of say we approve what you're doing until
5 we also check that out, can we?
6 MR. HACKETT: This obviously needs to be
7 addressed. It's a fundamental assumption. Terry
8 Dickson is here, who is the author of the FAVOR Code.
9 I think Terry would say if this assumption were
10 grossly violated we couldn't use FAVOR the way it's
11 currently configured.
12 So we do need to document that. I'm
13 hoping it means that this NUREG won't be thicker.
14 Like David indicates, I'm hoping it means that we can
15 refer to another document that will cover that in
16 detail, because we agree that has to be, that has to
17 be documented.
18 DR. KRESS: In general the, where the
19 water first comes in to the downcomer the thermal
20 shock is worse but the embrittlement is a lot less.
21 So those things offset each other until you get to the
22 beltline, which is probably your worst condition.
23 So you're primarily interested in the
24 thermal shock at the beltline?
25 MR. BESSETTE: That's correct.

1 DR. KRESS: Yeah, and the thermal
2 hydraulics that were done, pretty much, you assume no
3 mixing, I think, so that you're using the coldest
4 temperature of the incoming. Don't you assume no
5 mixing in your --
6 DR. BANERJEE: This is opposite.
7 DR. KRESS: Just well mixed.
8 DR. BANERJEE: Yeah, in fact, I think we
9 need to see the uncertainty analysis because it's not
10 a convincing story to say it is well mixed.
11 DR. KRESS: Yeah, and that's why the OSU
12 tests are supposed to validate or confirm that
13 assumption.
14 DR. BANERJEE: Both the multi-dimensional
15 aspect and the well mixed assumption need to be
16 examined.
17 DR. RANSOM: By well mixed I guess you
18 mean node by node they're well mixed, right?
19 DR. BANERJEE: Well, there was, that's
20 something that Dave can explain in more detail as to
21 what the assumption is. So, but my impression was it
22 was a well mixed downcomer.
23 DR. RANSOM: Well, unless they use one
24 node for the entire downcomer, it would not be.
25 DR. WALLIS: Now you're talking about

computation. We're talking about reality.

DR. RANSOM: Well, reality --

DR. BANERJEE: Well, why don't we ask Dave what the assumption is.

MR. HACKETT: Either Dave or Jack Rosenthal would be able to --

DR. WALLIS: Maybe it's too much for today. We've got a lot to do today.

MR. HACKETT: There are a lot of things going on here, obviously, as Dr. Kress indicated. When the plume comes in, depending on the NSSS Vendor and how things are set up, not only do you have to get down to the beltline, but you have to get down to an embrittled beltline weld.

Which may or may not be in that vicinity of the coldest area of the plume. So there's an awful lot going on here, computationally. But we can get into that later. Maybe during part of David's presentation or take that as a take away.

DR. WALLIS: Yeah, I think we'll get to it when we get to David's presentation. He's going to be prepared

DR. KIRK: And David has as long as Alan talks to get prepared.

MR. KOLACZKOWSKI: I'm going to be brief.

1 DR. KIRK: What we wanted to do now is
2 walk through the details of the plant through-wall
3 cracking frequency estimates. And we're going to do
4 that in the sequence of a discussion of the PRA
5 analysis, followed by discussion of the thermal
6 hydraulic analysis, followed by a discussion of the
7 PFM analysis.
8 DR. RANSOM: Even on that previous slide,
9 I noticed you've dropped the heat transfer coefficient
10 already. You know, that that was never explained in
11 the write up. You know, you're going to pressure and
12 temperature versus time out of thermal hydraulics.
13 And indeed I understand now, after reading
14 the other report, why you can do that.
15 DR. KIRK: Well, that, now you're perhaps
16 reading too much into the graphic. And coming from a
17 guy who loves solid mechanics and got a C minus in
18 fluids, I just didn't include the heat transfer
19 coefficient because I still don't understand the
20 units.
21 But then again I talk in ksi square root
22 inch and everybody thinks I'm weird. So, no, we do
23 use the heat transfer coefficient. I apologize for
24 leaving that off. Alan. Alan Kolaczkowski, who is
25 our contractor in the, one of our contractors in the

1 PRA area was going to do the briefing on how we step
2 through the PRA analysis.
3 MR. KOLACZKOWSKI: Okay, on this slide you
4 see a blow up of the PRA portion. The Committee has
5 seen some of this before so I'll try to go through it
6 briefly and perhaps, I'm sure you'll slow me down if
7 you have a question somewhere.
8 The left-hand side shows, again, the PRA
9 part that eventually is providing both the sequence
10 definitions, in terms of the overcooling transients
11 that may present a PTS challenge that we need to
12 model, both thermal hydraulically and then eventually
13 in the fracture mechanics.
14 And, of course, the frequencies of those
15 sequences which, again, a number that's going to be
16 carried forward that ultimately is going to multiplied
17 by the conditional probability of vessel failure for
18 that scenario, to arrive at the through-wall crack
19 frequency, which is a yearly number.
20 While I'll explain this as if it is a
21 serial, done in serial fashion. Of course, in
22 reality, as with any PRA project, you tend to iterate
23 on these tasks. You go to Task 6 and then go back to
24 Task 2, etcetera, etcetera.
25 But I'll try to explain it in a serial

1 fashion for clarity. Obviously, the first thing
2 you've got to do is get a bunch of information. And
3 here is just highlighted really the three major inputs
4 that went into defining the scenarios that we had to
5 worry about.
6 Obviously, first look at all the old
7 information that was done before. At all the previous
8 PTS analyses. Started with that as a baseline from
9 which to then extend the current analysis.
10 We have done three specific plan analyses
11 and are working on the Calvert Cliffs. Obviously in
12 order to mode a plant-specific analysis, you've got to
13 get information from the plant. And again, as
14 highlighted here, just some of the major types of
15 information that was gained on each plant in order to
16 develop the models.
17 And then finally the last bullet, it
18 didn't stop there. There were almost continuous, in
19 fact, I don't know if any of the Licensees are here,
20 but they would probably tell you that we called them
21 too many times sometimes.
22 But there was continuous feedback of
23 information going back and forth between the Licensees
24 and us to make sure that the models had been developed
25 appropriately and actually did represent the as-built

1 plant condition.

2 In terms of the PRA model itself, looking

3 at it from kind of two general perspectives first.

4 You see in the top bullet, the initiators that we

5 looked at involved all kinds. Primary system LOCAs,

6 all types of transients which then have some

7 subsequent fault, such as a stuck-open secondary

8 relief valve or whatever as a result of the reactor

9 trip, which would then induce the overcooling

10 scenario.

11 So all types of transients were looked at,

12 steam generated tube ruptures, steam line breaks and

13 so on, on the secondary. Below that you see just sort

14 of major classes of groupings of accidents that are

15 included in the PRA models for the plants.

16 Noted here are overcooling events, both

17 with either controlled RCS pressure, where RCS

18 pressure remains high. Where RCS pressure perhaps

19 initially drops and then we get a repressurization

20 event.

21 Faults both in the RCS or the secondary or

22 combinations. And lastly, we looked at this under

23 both full power conditions, as if the trip occurred

24 while the plant is normally operating at full power,

25 as well as during hot zero power conditions.

1 Where you don't have the fission heat to
2 act as somewhat of a suppressant in terms of
3 controlling the down of the cool down event. So we
4 looked at both hot power, excuse me, hot zero power
5 and full power.
6 This is just an event tree format of
7 really saying the same thing that the previous slide
8 said. Across the top you see the major functions of
9 interest that we're worried about that can affect the
10 nature of the PTS challenge.
11 That is what is the status of the primary
12 integrity? What is the status of the secondary
13 pressure and secondary feed? And then what else is
14 going on in the primary in terms of force flow versus
15 natural circ, because that has something to do with
16 the potential for stagnation, as well as what's going
17 on with the pressure in the primary system.
18 And all this is meant to display here is
19 just that we looked at all various combinations and
20 interactions of those functions and what scenarios
21 could cause those types of interactions to occur.
22 And ultimately pass that information on to
23 the TH folks, etcetera, to model the plant thermal
24 hydraulically for the various types of scenarios, and
25 then again ultimately that was an input to the

1 fracture mechanics folks.

2 DR. WALLIS: Are you going to talk about

3 operator actions, are you?

4 MR. KOLACZKOWSKI: Yes, I am.

5 DR. WALLIS: Because what struck me was

6 how many of these seemed to be influenced by operator

7 actions.

8 MR. KOLACZKOWSKI: Yes, that is true, Dr.

9 Wallis. Part of that rigor that we talked about

10 earlier.

11 DR. WALLIS: Well, your rigor consists of

12 considering the operator action. But how you treat

13 them, I don't think there is a rigorous method. And

14 you certainly admit that there.

15 MR. KOLACZKOWSKI: I guess, well, I'm

16 about ready to talk about the operator action, so let

17 me see if I answer your questions, and if not, then

18 I'll try to be clearer.

19 That is part of the scope. I mean I think

20 it is important to recognize that for some kinds of

21 over cooling events, not in all cases, but in some

22 kinds, the operator plays a very key role in the how

23 severe the over cooling becomes.

24 And so clearly if we were going to do this

25 correctly we had to consider what the operator may or

1 may not do to either mitigate the event or perhaps
2 even exacerbate the event.
3 And we've tried to do that in the PTS
4 work. And so we've modeled, not only their successes,
5 but errors of omission. And let me point out, again,
6 adding to part of the rigor, if you will, we went to
7 great lengths to think about things that the operator
8 might do that would exacerbate the cooling situation.
9 And particularly looked at those things
10 that were procedure-driven. Where there are places in
11 the EOPs where, under certain conditions, because of
12 course we were trying to make sure that we prevent
13 under cooling events.
14 Where the operator will actually take
15 actions that will, to some extent, exacerbate the
16 cooling of the scenario. And so we wanted to make
17 sure that those actions were included in the model.
18 MR. LEITCH: Did you reach these
19 conclusions by observing operator actions in a
20 simulator or just by looking at the EOPs and see where
21 the likely errors of omission or commission could be,
22 could occur.
23 MR. KOLACZKOWSKI: All of the above. In
24 fact, I have a slide, which I'll get to, that will
25 describe that a little further.

1 MR. LEITCH: Okay.

2 MR. KOLACZKOWSKI: But the short answer is

3 all of the above.

4 MR. LEITCH: Okay.

5 MR. ROSEN: What does the parenthetical

6 words, procedure-driven, mean under acts of

7 commission?

8 MR. KOLACZKOWSKI: Well, just that while

9 we did do some amount of searching for, shall we say,

10 where the operator might just do something even though

11 the procedure may not even suggest that a certain act

12 be taken.

13 While we did do some searching for that

14 and did include one or two others that I can think of,

15 operator actions in the model that were of that type,

16 we found enough of places in the procedures where it

17 would direct the operator to enhance the cooling.

18 That clearly we wanted to make sure that

19 those were included in the model and that's were the

20 emphasis went. But we did try to think a little bit

21 more about what else might the operator do in a

22 realistic sense that maybe even isn't in the

23 procedure, where they would enhance the cooling.

24 And we did come up with one or two events

25 additional that are not necessarily in the procedures.

1

2 MR. ROSEN: Well, we'll come back to this
3 point, but let me let you go further.
4 MR. KOLACZKOWSKI: Okay.
5 DR. BONACA: Did you, you focused on the
6 three plants, of course, but did you look at these
7 precursors I was talking about before? I mean there
8 are precursors, particularly for B&W plants and also
9 for Robinson's there are two that led to extreme cool
10 downs. Did you look at those?
11 MR. KOLACZKOWSKI: Yes, we did. And we
12 tried to look at the types of errors that operators
13 have made in the real events, again, as a check to
14 make sure are we including those types of acts in the
15 model?
16 And so it was an input into deciding what
17 ought to be modeled, yes.
18 DR. BONACA: Because, I mean, I know these
19 plants had significant modifications because of those
20 cool downs. And also clearly a big modification has
21 been the EOPs which are system-oriented.
22 But we can't understand how they could be
23 still defeated, for example, in the EOPs, to get back
24 to transients that such as severe as this.
25 MR. KOLACZKOWSKI: Well, as I said, you

1 don't even have to defeat the EOPs. You sometimes, in
2 following the EOPs, you will enhance cooling which
3 could, at least, be a potential challenge in PTS
4 space.
5 DR. BONACA: The reason why I raise the
6 issue of steam line break is because, you know, a
7 break used to be the limiting transients before. And
8 now they have disappeared from the horizon. We don't
9 have them anymore.
10 And I, you know, when I saw the previous
11 analysis, it was very strange to me. But you
12 understand that that's really an area where we have to
13 drill because the whole scenario has changed.
14 MR. KOLACZKOWSKI: I understand, and as
15 Mark pointed out, the operator action credit is only
16 one of three reasons why the secondary faults go away.
17 And when we get to that point hopefully it will become
18 clearer.
19 DR. BONACA: But it disappear as a steam
20 line break is a big contributor I understand. I don't
21 know what is the factor or contribution, but I believe
22 it is a significant contribution in degrees, isn't it?
23 MR. KOLACZKOWSKI: In the early work, in
24 the Oconee work, I think the main steam line breaks
25 were close to 50 percent contributors and now they're

1 more like five percent or less.

2 DR. BONACA: Yeah, yeah, so it's a big,

3 big contributor. Okay.

4 MR. KOLACZKOWSKI: Yes. These are the

5 classes, if you will, of human failures that we tried

6 to consider. And what is indicated is the function of

7 going and looking at those four functions on the event

8 tree that you saw earlier.

9 The function which those actions most

10 affect. Now actually some of these actions affect

11 more than one function at a time, but we tried to, for

12 category purposes, associate them with the function

13 that they most affect.

14 And I guess the only point I want to make

15 about this is that not only will you see so-called

16 errors of omission in this list, but as I said, we

17 tried to consider things that the operator might do in

18 an act of commission which might worsen the over

19 cooling scenario.

20 Just to take an example, if you look at

21 the first column there, Primary Integrity. Not only

22 do we look at things like where the operator would

23 fail to isolate and isolable LOCA, which would be an

24 error of omission, where the procedure says make sure

25 you close off all isolable paths first in case indeed

1 that's the source of the LOCA.

2 And if the operator failed to do so, the

3 cooling would continue because the LOCA would

4 continue. But we also looked at situations where,

5 what would induce the operator to cause a LOCA and

6 would again exacerbate the cooling situation.

7 And there are places in the procedures

8 where operators do induce LOCAs under certain

9 conditions. And we tried to make sure that that's

10 included in the model.

11 MR. ROSEN: Now maybe this is the right

12 time to ask my question about uncertainty and

13 particularly the kind of uncertainty that has troubled

14 this Committee most, which is model uncertainty.

15 And that goes to the question of what

16 haven't you included in this which could dramatically

17 change the PRA result feed into the thermal hydraulics

18 result feed into the fracture mechanics results and

19 lead to you an answer which isn't real.

20 An answer that says that pressurized

21 thermal shock is very unlikely and therefore we can

22 raise the criteria and let plants run longer than they

23 would have otherwise been able to run. So you get to

24 the wrong answer in the regulatory frame work if you

25 get this problem wrong.

1 And where it could get wrong is right
2 here. Not including things that could lead to
3 pressurized thermal shock, that operators do, could
4 do. Now you've made a pass a that, clearly, by
5 including acts of commission. And I applaud that.
6 But have you attempted to go beyond your
7 statements of, that this is a rigorous analysis, grant
8 that. But also say, but, we don't know that we've
9 concluded all the model uncertainty.
10 In fact, it's unknowable. And so we need
11 to do something with that knowledge, that we have an
12 unknowable condition. We need to factor these results
13 in some reasonable way. Do you understand my
14 question?
15 MR. KOLACZKOWSKI: I think I do, Dr.
16 Rosen. And let me try to answer it now and hopefully
17 again with further slides in the presentation may it
18 become clearer. But let me make, I guess, a couple of
19 points.
20 First of all, we have done and are still
21 doing, as you see some of the ongoing work, additional
22 sensitivity analyses. Where we can do things like,
23 well, what if we're wrong? Well, what if the operator
24 error probability were one?
25 Would it make a difference? How much

1 higher would the main steam line break scenario
2 become, etcetera? And we're in the process of doing
3 those kinds of things.
4 What we're finding so far is that we would
5 have to be so grossly off, it seems. And I know it's
6 hard to define what gross is. But we would have to be
7 so grossly incorrect for the conclusions to change,
8 that it almost seems inconceivable.
9 The other thing is if you look at what the
10 dominant results are, you will see that LOCAs seems to
11 dominate. In LOCAs, operators, for the most part,
12 especially if the LOCA is much beyond, say, three or
13 four inches in equivalent diameter size.
14 There's not much the operator can do
15 anyway. Short of shutting off the HPI a la TMI, all
16 they can do is let the event happen. The cool down is
17 going to happen at whatever rate it's going to happen,
18 which is largely defined by the break.
19 And the operator is essentially out of the
20 picture. So, with the exception of, you know,
21 recognizing that we have taken operator credit for the
22 secondary faults, otherwise we said, there are other
23 reasons why secondary faults are also not as
24 important, that are thermal hydraulic-driven,
25 etcetera.

1 That aside, if the LOCAs then really do
2 dominate, the operator is not that important part of
3 the equation on how important these events are. So,
4 I guess, I don't want to overemphasize the operator
5 actions here.
6 Because if indeed if we're right and the
7 LOCAs are the dominate types of over cooling scenarios
8 to worry about, for the most part, especially in the
9 larger size breaks, the operator is out of the
10 equation anyway.
11 So it's not so important to completely try
12 to quantify every little bit of the uncertainty.
13 We'll try to, I'll try to show you what uncertainties
14 we have addressed. You're really asking the age old
15 question, how do you know you've been as complete as
16 you can possible be?
17 Peer Review, discussions with Licensees,
18 presentations in front of the ACRS. The subsequent
19 Peer Review we're going to do. We're doing about
20 everything we think we can do to say, have we
21 addressed the issue sufficiently? Nathan?
22 DR. SIU: Yeah, I just wanted to add to
23 that. Without overstating the, or over using the word
24 rigor, we've tried to be systematic. And there is a
25 systematic process that the team used to identify not

1 only the human failure events in the model, but the
2 conditions that would lead to reasonably high
3 probabilities for those human failure events.
4 So it's not just a model that says this is
5 the ATHEANA approach, which I think many on the
6 Subcommittee have heard about. It's not just a matter
7 of saying here's a human failure event and there's a
8 random probability.
9 No, there's a search process that tries to
10 identify what are the contextual factors that would
11 tend to increase the likelihood of that event in the
12 PTS example. And then, so it's that process that
13 gives us some degree of confidence that we aren't
14 missing things.
15 Now obviously you can't claim that you're
16 perfect. But, again, I wouldn't necessarily claim
17 rigor here. But it is a state-of-the-art or perhaps
18 beyond state-of-the-art analysis.
19 Clearly, there are some places where human
20 reliability analysis was weak. We've talked to the
21 Committee before about our research program in this
22 area and the area of quantification.
23 For example, it's not what you would, a
24 process that you would say is rigorous, but it's
25 systematic and it makes use of available information

1 as best we can. And as Alan indicated, we do take
2 input from observations of actual crews. We talk to
3 trainers.
4 So it's not just the analysis team
5 huddling together and dreaming up something.
6 MR. KOLACZKOWSKI: Let me just highlight.
7 This is the first step of that systematic process. I
8 mean if you decide, if you agree these are the
9 functions of concern, our first question was rather
10 than just sort of dreaming up, well, what could the
11 operator do wrong?
12 We said how could the operator effect each
13 of those functions. And this is the first step of that
14 systematic process. Trying to decide how the operator
15 can affect each function. And then from there, then
16 going the next step and starting to derive the
17 specific actions that could occur, that would then
18 affect those functions and then include those in the
19 models.
20 This is actually the first step of that --
21 DR. WALLIS: Then you'll get probability
22 on those various actions.
23 MR. KOLACZKOWSKI: Yes.
24 DR. WALLIS: And that's where I think
25 we're probably the weakest. Because you have to

1 imagine what the person would do, and then you've got
2 to put some number on it. And this is done, I
3 understand, by expert elicitation?
4 MR. KOLACZKOWSKI: That is correct.
5 MR. ROSEN: And the expert elicitation in
6 that case would be, for example, under primary
7 integrity control, how likely is it that an operator
8 will induce a LOCA by operating outside his procedure?
9 Or by operating with inside his procedure, at a time
10 that he should really do the things we're postulating
11 him to do.
12 So I mean now you're presenting that to
13 trained operators. And my guess, they'll
14 underestimate it.
15 MR. KOLACZKOWSKI: Actually, interesting
16 enough, and we'll get to it. But when we did the
17 Palisades analysis we did a collaborative HRA effort.
18 And actually the elicitation team was formed by a
19 composite group of operators, EOP writers in the
20 Licensee, as well as NRC contractors.
21 Interestingly enough, sometimes the
22 Licensee people came up with higher failure
23 probabilities than the NRC contractors did. And that
24 was included.
25 MR. LEITCH: Have you considered the

1 possibility that operator performance in the simulator
2 may be considerably better than in the real world?
3 MR. KOLACZKOWSKI: I think we're all aware
4 that, you know, whenever an operator is in a simulator
5 they know, you know, way, way in the back of their
6 mind somewhere, they know it's a simulation.
7 And you try to consider that. I, I don't
8 know how else to address that.
9 MR. ROSEN: Well, and also this Committee
10 has commented on the fact that the operating crews in
11 simulators are the crew rather than the real case
12 where the crew in the plant at 4:00 in morning on
13 Saturday is two-thirds of the real crew and a third of
14 make-up people.
15 People who are relieving someone else who
16 is in the real crew but doesn't have to be here
17 because he's on vacation of some other reason. So
18 it's a fact of life that performance in the simulator,
19 for several important reasons, is better, can be
20 expected to be better than what we will see in the
21 plants.
22 MR. KOLACZKOWSKI: All I can say is that
23 in the elicitations, in all of the elicitations for
24 all of the plants, we, when we posed the various
25 questions of the probabilities we had to come up with,

1 we tried to put uncertainties, of course, on the human
2 error probabilities we were coming up with.
3 And we, when we asked the elicitated group
4 to think about those probabilities, we asked them that
5 at the high end they needed to think about things like
6 what if this was at 4:00 in the morning on the worst
7 day of days.
8 You know, you had other problems and
9 nuisance alarms going on, etcetera, etcetera. And try
10 to, as part of the elicitation process, capture not
11 only, if you will, the nominal, normal state
12 condition, but what are the extremes at the two ends.
13 When everything is going well, and when
14 everything is going bad. And all I can say is many of
15 our 95 percentile valves on our human error
16 probabilities are numbers like .8 failure probability,
17 .7 from the elicitation group.
18 We think we've captured that in our
19 uncertainty on our HRA numbers. As best as the
20 state-of-the-art allows.
21 MR. ROSEN: I hate to do this, but just to
22 bore you just a tiny bit more.
23 MR. KOLACZKOWSKI: Sure.
24 MR. ROSEN: On the idea of getting numbers
25 out of this group. What, did you attempt to anchor

1 the group is some other actions that they know much
2 better than the ones that you were questioning them
3 on? You know, the anchor techniques that are in the
4 literature.
5 MR. KOLACZKOWSKI: Yes, we did. In fact,
6 and again, part of the ATHEANA work talks about
7 G-cars, which are basically anchoring numbers. Trying
8 to take operators and first explain to them actual
9 events that have happened and how we assess,
10 therefore, some probabilities associated with those
11 acts to try to anchor the team, etcetera, before
12 moving on.
13 And that was certainly part of the
14 process.
15 MR. ROSEN: I'm not done on this subject.
16 MR. KOLACZKOWSKI: That's fine.
17 MR. ROSEN: But let's leave it there for
18 now.
19 MR. KOLACZKOWSKI: Okay.
20 DR. BANERJEE: What impact did operator
21 actions have on the RPT failure probabilities in that
22 curve?
23 MR. KOLACZKOWSKI: Well, as I pointed out,
24 if indeed we are correct that LOCAs dominate and
25 particularly the, getting into the larger size LOCAs,

1 then the operator really plays very little role at
2 all.
3 Because, as I said, once the break occurs,
4 the cool down is going to go at whatever rate it's
5 going to go. The pressure is going to do whatever
6 it's going to do. More than likely, especially after
7 Three Mile Island, operators are not going to just go
8 shut the HPI off.
9 So we're hitting the downcomer wall with
10 cold water and it all becomes a T-H fracture mechanics
11 game, and the operator is pretty much out of the
12 picture.
13 The operator does provide some mitigating
14 and/or exacerbating role in what happens to secondary
15 faults, because that he has more control over. He can
16 isolate a faulted steam generator.
17 He can close off an isolation valve on a
18 stuck open atmospheric dump valve the ends the event.
19 Or, he can open a valve, because he thinks it's the
20 right thing to do. And we've included those kinds of
21 situations in the model.
22 So he has much more affect on the
23 secondary side. The primary side, there's really not
24 much the operator can do, short of shutting off the
25 HPI water and then it's not a PTS event it's a core

1 melt event.

2 DR. BANERJEE: So the effect of operator

3 actions doesn't shift that curve we saw some time ago

4 which was done with this one code?

5 MR. KOLACZKOWSKI: That is correct. We

6 would have to be vastly, vastly way off on our

7 secondary effects in order that suddenly steam line

8 breaks become super important and it raises the whole

9 curve, etcetera and so forth. And I think that's very

10 unlikely.

11 DR. SHACK: I'm going to suggest we take

12 a break here. I sort of hoped we were going to get

13 the PRA.

14 MR. KOLACZKOWSKI: So did I.

15 (Laughter.)

16 DR. SHACK: But I see that we're not going

17 to do that in a reasonable time. So I'd like to take

18 a break for 15 minutes and we'll come back in 15

19 minutes.

20 (Whereupon, the foregoing matter

21 went off the record at 10:09 a.m. and went back on the

22 record at 10:26 a.m.)

23 DR. SHACK: Let's go through the material

24 in as much detail as we need to, because I think

25 that's the most important thing. So I'm going to try

1 to, I'll let that run. I want to protect the time
2 that we've set aside to talk about the acceptance
3 criteria, because I think that's another, and the
4 containment-type issues.
5 What we may end up doing is short-changing
6 the plant-specific results somewhat. Simply because
7 there is not enough time. And that, and so I've sort
8 of briefed the staff that that's the way we want to
9 go.
10 But just remember, the longer we spend on
11 the general material, the less time we're going to
12 have to look at the plant-specific results, because at
13 some time later in the day I'm just going to call an
14 end to it and say we're going to go on to acceptance
15 criteria.
16 Just so we can cover that rather important
17 issue. Meanwhile, back at the PRA.
18 MR. HACKETT: Yes, so Bill, per the
19 current schedule then, I think everyone has that on
20 their cover sheet. We are probably going to get
21 through the rest of Alan's presentation and then the
22 discussion on thermal hydraulics and RELAP this
23 morning.
24 And then you're welcome to weigh in
25 afterwards when we go to the plant-specifics, we can

1 limit that discussion as needed. Another thing I was
2 going to say, during the caucus, some of the team was
3 discussing, and maybe we didn't make this clear enough
4 so I'll try to that now.
5 The focus, of course, of this project is
6 on development of technical basis and technical basis
7 evaluation. So I think Dr. Ford asked earlier and
8 maybe there was some other discussion along the lines
9 of is this, you know, are we so far down this path
10 this is irreversible?
11 Are there things going on that we're not
12 going to be able change? And of course the answer is
13 no. There is, as everyone knows, or should know well
14 around here, nothing happens real fast, particularly
15 when you get to rule making.
16 So I think the question was asked can we
17 engage, can NRR engage on rule making while we're
18 finalizing some these technical aspects, and of course
19 the answer is absolutely yes.
20 Now what if we're down the path at some
21 point and we find what we think is a show stopper?
22 Does that indicate that we can, you know, should we
23 shift directions? And the answer to all of that is
24 there's ample opportunity to do that.
25 When you get into rule making, as the

1 Committee knows, there is probably, particularly with
2 an issue as complex as this, you're probably looking
3 at about two to three years worth of rule making
4 process.
5 From us drafting the rule to the internal
6 consideration by Committees like ACRS, also CRGR,
7 internally. Opportunity, at least twice, for public
8 comments, detailed public comments, which the staff
9 has to address.
10 So there will be numerous opportunities,
11 as we go down this path in the future, to address some
12 of the other concerns. But I just thought I'd state,
13 for purposes of the record here and what we're trying
14 to achieve, that this is still at a tech basis.
15 We still have to obtain agreement from NRR
16 that they think we're there. We think we do have
17 that. We obviously have to, hopefully, get some kind
18 of consensus or agreement with ACRS and other bodies
19 as to, you know, the merits to proceeding with this
20 type of thing.
21 So, the bottom line is this is all very
22 valuable to us and it's not a final product, but we're
23 working towards that, obviously, as a goal and really
24 appreciate the interactions with the Committee in that
25 regard.

1 DR. KRESS: Since you already have a PTS
2 rule in the books, and basically all you're doing is
3 changing the screening criteria, shouldn't it be
4 pretty easy to write a rule?
5 MR. HACKETT: I would, you know, I would
6 hope so. Although, I guess, I know personally, I've
7 been down this path a number of times and a number of
8 the people in the room have too.
9 It invariably is a process that cuts both
10 ways. And I think by intent it's not suppose to
11 operate rapidly. It's suppose to give, for the NRC,
12 for instance, suppose to give the public a chance to
13 engage, to have people critique things.
14 So it would probably still be minimum a
15 two-year process would be my best guess. Now, if
16 there's a petition for rule making or potential for
17 direct final rule making, I think that can be
18 accelerated.
19 In practice, it still takes time. It's
20 still, you know, probably more like 18 months than if
21 everybody lines up in agreement with.
22 DR. KRESS: The only reason for urgency
23 might be in some plant wants to come in for license
24 renewal and this is an issue with them.
25 MR. HACKETT: Correct. With that, I'll

1 turn it back over to Alan.

2 MR. KOLACZKOWSKI: Okay, I guess

3 continuing on. And the first two steps again was

4 collect information. By the way, I want to point out

5 -- could you go back to Step One, just for a moment.

6 Yeah. You'll notice that with regards to

7 the human part, I just wanted to highlight a couple of

8 bullets. Both the, we looked at the emergency and

9 abnormal operating procedures.

10 We looked at training material. We talked

11 to actual crew operators at the various plants,

12 etcetera, to get a feeling for how sensitive or not

13 they were to over cooling events. To what extent it's

14 handled in their training.

15 How often they actually simulate over

16 cooling events, etcetera. And then I also wanted to

17 highlight the last bullet, observe simulator

18 exercises. At each and every plant, all four of them,

19 we simulated something like, it varied from

20 plant-to-plant, but anywhere from two to four over

21 cooling scenarios.

22 Some LOCAs, some secondary faults,

23 etcetera. And observed how fast it took them to get

24 through various steps in the procedures. When they,

25 actually in one or two cases we found some places

1 where procedures could actually be improved a little
2 bit.
3 And the Licensees took actions, in fact,
4 to do that. It might have been a minor point of
5 confusion or whatever, but the point is we simulated
6 quite a few number of scenarios and observed the crews
7 working through those scenarios, so I just wanted to
8 highlight that as well.
9 Now if we can go back to Step Three, which
10 is where we were. Okay, so we've set the general
11 scope of the model. The types of over cooling
12 scenarios we want to include.
13 As I pointed out, the human does play a
14 very important in some over cooling scenarios. We
15 wanted to make sure that that aspect was also included
16 in the model.
17 Now, I want to talk a little bit about the
18 model constructions themselves. While they are all
19 event tree,. fault tree-based, typical of PRA process,
20 there are some differences among the models, and I
21 wanted to point out what those differences are.
22 Not that the differences have any affect
23 on necessarily the resolution of the answer or
24 anything like that, but just that the construction
25 process did differ a little bit and I just want to

1 highlight what those differences are.

2 Okay, so first of all the Oconee model was

3 the first one that we constructed. A couple of key

4 aspects to recognize, this was one of the plants were

5 the NRC contractors built the model by collecting

6 information from the plant and then obviously having

7 many phone calls and e-mails to deal with questions or

8 issues as they might have come up.

9 The HRA, the Human Reliability Analysis,

10 was initially performed by the NRC contractors. In

11 other words, the expert elicitation panel was solely

12 NRC contractors. But then that information was then

13 reviewed by the Licensee.

14 And I'll point out a process when that was

15 done. Also, additionally, the initiating event

16 frequencies and the equipment failure data that are in

17 the model are based on industry generic data.

18 That is they are not necessarily

19 Oconee-specific initiating event frequencies or

20 Oconee-specific failure probabilities of equipment.

21 In that case we used actually generic data, trying to

22 take data that was representative across the industry.

23 Because, again, ultimately we're trying to

24 get an industry-wide solution to the PTS problem and

25 not necessarily try to answer specifically what

1 Oconee's specific PTS risk is. But the human
2 reliability analysis was based on Oconee's procedures,
3 Oconee's training and so on and so forth.
4 When we were constructing the model,
5 because it was the first one, we did not yet have
6 preliminary thermal hydraulics of fracture mechanics
7 information available to us. So, as a result, we
8 didn't a priori screen out any times, any types of
9 over cooling events in the PRA model.
10 Because we didn't know whether or not they
11 could be screened out. So using the word all in
12 quotes, the Oconee model is probably the most complete
13 of all of them, relative to the over cooling scenarios
14 that are included in the PRA model.
15 So, for instance, even if we had a
16 secondary fault or just some small secondary valve
17 opened up in the scenario that we were modeling, where
18 later on we came to find out that that was a very
19 unimportant scenario, it's included in the model
20 because, again, we didn't have any preliminary
21 information from the thermal hydraulics or the
22 fracture mechanics that we could, with confidence, say
23 well that's a scenario we don't need to model, we know
24 it's not going to be important.
25 So the Oconee model includes,

1 quote/unquote, all the over cooling scenarios that we
2 could think of. The Beaver Valley model is different.
3 It was the second model that we developed, and just
4 because of when it was occurring time-wise, again,
5 this was a model that was built by the NRC
6 contractors.
7 And then again reviewed with input from
8 the Licensee. HRA was performed in a similar way.
9 Same point made about the data. But, but that point,
10 we had some preliminary information coming back on the
11 results, the integrated results from the Oconee.
12 And we were learning that certain kinds of
13 scenarios were likely to be unimportant. Couple that
14 with the fact that by the time we were constructing
15 the Beaver Valley model, we already had some 40 or so
16 T rails run on Beaver Valley.
17 So we had some thermal hydraulic
18 information and we had preliminary fracture mechanic
19 information. We already knew that some scenarios were
20 going to be relatively unimportant, from a
21 through-wall crack frequency perspective.
22 So, as a result, we simplified the Beaver
23 Valley model development and purposely did not model
24 certain kinds of scenarios in the Beaver Valley model,
25 because we had enough information from the TH and

1 fracture mechanics, that we knew that those were going
2 to be, if you will, non-challenging PTS events.
3 The next slide or two I think just
4 illustrates some of the simplifications we made in the
5 Beaver Valley model. I guess if the Committee has any
6 specific questions, we can address those now or at a
7 later point.
8 But I just wanted to highlight what some
9 of the simplifications were. Next slide. And next
10 slide. Palisades was the last model that we
11 developed. And again, the Calvert Cliffs model is
12 ongoing now and I will not address that, per se,
13 unless there are questions related to it.
14 Because we're just starting in the Calvert
15 Cliffs process. The Palisades was the last of the
16 three that are in the report. This model was
17 developed differently. In this case we, the Licensee
18 was really, if you will, the keeper of the model.
19 Palisades, in their IPE and updated since
20 model of the core damage frequency, had PTS scenarios
21 already in the model. So, in this case, what we did
22 was we took the Licensees model of the PTS scenarios.
23 We reviewed, the NRC contractors provided
24 comments and input to the Licensee on other
25 considerations that we thought they ought to include

1 in their model. Palisades changed the model
2 accordingly and then they ran the model.
3 We then reviewed the results and worked
4 with them in making sure we interpreted the results
5 correctly. So the point is here, rather than the
6 contractors building the model, we started with a
7 pre-existing model and modified it.
8 But the Licensee was, if you will, the
9 keeper of the model. As I pointed out in this case,
10 whereas in the other two plants you saw the NRC
11 contractors did the HRA work initially and then it was
12 reviewed and input was provided by the Licensee, in
13 this case this was a collaborative effort.
14 We actually went up to Palisades, spent
15 three or four days there, and as I pointed out, we got
16 actual crew operators, trainers, one person was an EOP
17 writer, along with NRC contractors and formed a team
18 of about, I think was about six or seven people.
19 And we went through the HRA process
20 together to come up with the failure probabilities
21 that would be included in the model. So it was much
22 more of a collaborative, hands on, working together
23 kind of effort.
24 And as I pointed out, Dr. Rosen, it was
25 interesting that sometimes the Licensees came up with

1 higher failure probabilities than the NRC contractors
2 did. Probably because they know the situation, they
3 understand the situation better.
4 And they know where they could get fooled
5 or where they might make mistakes. Okay, now we've got
6 the models built. We did an initial quantification.
7 We basically quantified all the action sequences.
8 Just to give you some feeling. In the
9 Oconee model, the one that I said was the most
10 complete from an overall number of scenario
11 perspective, because we didn't a priori rule out any
12 scenarios.
13 Donnie, what is there, 118,000 over
14 cooling sequences, or something? Is that right?
15 DR. WALLIS: One hundred eighty-one
16 thousand two hundred and fifty-eight.
17 MR. KOLACZKOWSKI: Thank you, Dr. Wallis.
18 (Laughter.)
19 MR. KOLACZKOWSKI: Again, the Beaver
20 Valley model has much less sequences because we were
21 able to do some simplification, as I pointed out. And
22 the Palisades model is probably somewhere in between
23 the two.
24 Now we cannot run 181,000 different TH
25 scenarios. We'd still be here working on it. The

1 RELAP runs take a little bit more time than that. So
2 clearly we had to do some binning.
3 And so what we did was we took like
4 scenarios, similar in terms of what we expect their
5 characteristics would be. Put those into bins and
6 then those bins were what were actually analyzed by
7 the TH folks, and then subsequently the fracture
8 mechanics.
9 Let me point out this is a much, this is
10 a very iterative process. We took an initial crack at
11 the binning, got some results. That told us that
12 either we binned in some cases too grossly, and some
13 cases perhaps overly binned and we could combine some
14 things.
15 So then we redid the binning process, if
16 necessary, based on the PFM results, etcetera. So,
17 again, while I'm explaining this as if it was a serial
18 process, I want to point out it was actually quite
19 iterative to make sure that the binning was of the
20 proper resolution that we felt we needed to get the
21 results.
22 MR. ROSEN: And I'm assuming the iteration
23 went on at the PRA level too, between them. In other
24 words, you learned something at Oconee that you
25 applied at Palisades, and then you learned something

1 at Beaver that you apply to Oconee.

2 MR. KOLACZKOWSKI: Absolutely, absolutely.

3 And that started right at the beginning, at least

4 looking at the old PTS stuff back done in the 80's.

5 And then, and looking at things that, well, maybe in

6 one study they did something that they didn't treat in

7 another study, so we wanted to make sure, well let's

8 make sure that we treat that in all the analyses,

9 etcetera.

10 And it was a constant learning process.

11 DR. KRESS: Educate me a little bit on

12 binning. When you take a thermal hydraulic sequence

13 and you get some sort of severity criteria for that

14 sequence, which may be the nature of the shock or the,

15 and the pressure combined or something.

16 And you want to put a bunch of these

17 sequences in a bin related to that severity, ah,

18 severity range. Now, when you go to use that bin in

19 your PRA, do you use the most severe one or do you use

20 a mean or what do you use out of that bin?

21 MR. KOLACZKOWSKI: Okay, well first of

22 all, let me indicate in a way, if I understand your

23 point, in a way it's the other way around. The PRA is

24 developing hundreds of thousands of sequences.

25 Now we need to take those and put those

1 into a, I think for Oconee we ended up doing something
2 approaching 180 or so bins that we looked at. So
3 we're taking 100,000 sequences and trying to put them
4 into, roughly, a couple of hundred bins.
5 And what you do, effectively what we did
6 was we, we first of all did some various types of,
7 gross types of different types of scenarios. LOCAs of
8 different sizes. Secondary faults with one valve
9 open, with four valves open, etcetera.
10 And got at feeling, first of all, how much
11 did the thermal hydraulics change under these various
12 conditions? By that, and then run it through the
13 fracture mechanics code, get some conditional
14 probabilities of vessel failure. See how much those
15 are changing.
16 Now you are beginning to learn where the
17 sensitivities are. Where you need to bin very finely
18 because whether you open one valve or two valves,
19 seems to make a big difference on the thermal
20 hydraulics, and/or therefore potentially makes a big
21 difference in the CPF.
22 Versus other areas where you find out,
23 gee, if I open up one valve or four valves, the
24 thermal hydraulics hardly changes at all, so we can
25 group all of those sequences, whether it be one valve,

1 two valves, three valves or four valves.

2 Put them all into one bin, it's good

3 enough. And so that's where the iteration comes in.

4 I mean we tried some gross ones first, and then we

5 learned from that. We began to recognize where we had

6 to bin very finely.

7 Where we could continue to bin very

8 grossly. Because the ultimate results just either

9 were or were not very sensitive to the binning. And

10 so --

11 DR. KRESS: Once you get a bin, do you

12 have to select a representative set of thermal

13 hydraulics for that bin?

14 MR. KOLACZKOWSKI: Yes.

15 DR. KRESS: My question now is how do you

16 do that? There are some differences.

17 MR. KOLACZKOWSKI: The bin was actually

18 run based on, for example, let me take the case where

19 suppose, let's say, one to four valves does not make

20 that much difference, okay?

21 What we would do is we would give the TH

22 folks the scenario that they needed to actually run.

23 The worst case, if you will. That is we would say,

24 okay, then if it doesn't make that much difference,

25 let's have them run the scenario as if four valves

1 open and remain open.

2 And that's the scenario they're going to

3 run and that's the scenario they ran.

4 MR. ROSEN: So what four valves are you

5 talking about in that case?

6 MR. KOLACZKOWSKI: Four turbine bypass

7 valves open versus one, for instance. Something like

8 that. Or three ADVs versus one or three main steam

9 safety reliefs versus one.

10 If it doesn't make that much difference,

11 we had them run the worst case.

12 DR. KRESS: So binning, and I can conclude

13 from what you say, is a source of conservatism,

14 possibly?

15 MR. KOLACZKOWSKI: Yeah, where, where

16 certainly once we created a bin to represent that bin

17 we hopefully always tried to represent what we thought

18 was the worst scenario that was still within that bin

19 structure.

20 DR. KRESS: But then you're going to put

21 an uncertainty band on that to do the uncertainty

22 analysis?

23 MR. KOLACZKOWSKI: Well, there is an

24 uncertainty about the frequency of that bin, as well

25 --

1 DR. KRESS: That's on the frequency.

2 MR. KOLACZKOWSKI: Yeah, on the frequency

3 of the bin. I'm not sure what you're --

4 DR. KRESS: Well, I was thinking about the

5 thermal hydraulic uncertainty also on that.

6 MR. KOLACZKOWSKI: Oh, yes.

7 MR. ROSENTHAL: Let me, Jack Rosenthal,

8 Safety Margins and Systems Analysis Branch and

9 Research. In fact we ran over a hundred RELAP runs

10 for each of the plants. I keep getting back to the

11 fact that we start out at about 550 F and we end up at

12 like two or 300 F and it takes about two hours to get

13 there.

14 And so you, if you knew nothing but some

15 basic mass and energy constraints and had a

16 calculator, you would draw some sort of line, you

17 know, between those points. And then in another one,

18 and you know, it seems to me, relative to what we

19 think we know about the total, how well we can do the

20 predictions, we're slicing this pie rather fine.

21 So that I just wouldn't expect that the

22 binning, within so many bins, that you're taking the

23 worst within that bin, but there are so many of the

24 bins that were really, that there's fine distinctions

25 that have meaning.

1 MR. KOLACZKOWSKI: Let me point though, I
2 mean we did a lot more binning in the early work. I
3 mean the 80's work, if you look at how many bins they
4 analyzed to then base their, the original PTS rule.
5 I mean they were looking at something
6 approaching a dozen bins. We're looking at a hundred
7 and something bins. And so from that perspective, we
8 think we've removed some of the conservatisms.
9 As an example, in the early work where
10 they might have said whether it was one turbine bypass
11 valve versus four versus a main steamline break, we'll
12 treat it all as if it's a main steamline break.
13 And therefore we're grossly over
14 estimating the amount of the cooling you'd get with
15 one or two stuck open turbine bypass valves. We've
16 removed that conservatism by saying, well, there is a
17 difference between a main steamline break and one
18 stuck open TBV.
19 So we'll have a bin that represents one
20 stuck open TBV and we'll have another bin that
21 represent the main steamline break. Okay, I guess,
22 moving on. So we had the bin and then eventually --
23 DR. BANERJEE: I have one question. Did
24 you sort of make the bins which contributed to risk
25 more fine than the ones that did not?

1 MR. KOLACZKOWSKI: The answer to that is
2 yes. For example, as I said, LOCAs dominate. And
3 originally we only started off with essentially three
4 LOCAs in our model. A small LOCA, a medium LOCA and
5 a large LOCA.
6 Small being something representative
7 around two inches or so equivalent in diameter.
8 Medium in the neighborhood of five or so, six inches
9 in equivalent diameter. And then large being
10 something like ten, 12, 14, all the way up to 22
11 inches actually we looked at.
12 When we recognized that those were going
13 to dominate the PTS risk, we then took each one of
14 those and further binned them into subsets, having to
15 do with a number of variations that we treated in an
16 uncertainty way, not only the size of the break but
17 the amount of HPI flow.
18 What if it was 110 percent flow, what if
19 it was only 80 percent flow, in terms of the cold
20 water hitting the downcomer, and so on and so forth.
21 So we binned those yet into further bins because we
22 recognized we needed to be finer because this is where
23 the dominate results were. So the answer is yes.
24 DR. WALLIS: Now what's happened as a
25 result of your work, it seems to me, is that the order

1 of things has been changed and turned upside down.
2 Large LOCAs that previously were unimportant are now
3 the dominate sequence and so on.
4 Is that because of something that's been
5 changed in the PRA? Is it something that's been
6 changed in the way --
7 MR. KOLACZKOWSKI: Go to the slide with
8 the green and red arrows.
9 DR. WALLIS: -- I can't the materials
10 makes any difference. I mean if it's a bigger
11 challenge, then it's going to be a bigger challenge.
12 And what you've done to refine the materials analysis
13 isn't going to make any difference.
14 What is it that's turned, that's reversed
15 the order of importance of these events?
16 MR. KOLACZKOWSKI: We showed you this
17 slide earlier. I mean recognize, we're making a lot
18 of changes from what was originally done in the early
19 work, in the 1980's work.
20 DR. WALLIS: PFM doesn't do that does it?
21 PFM doesn't change the order of importance of the
22 scenarios?
23 DR. KIRK: But how the scenarios have been
24 represented to the PFM can, and in terms of the
25 contribution of medium to large break flow because, I

1 think is part of the genesis of your comment.

2 DR. WALLIS: It leads to that, yes.

3 DR. KIRK: The fact of the matter is, is

4 that they had been previously excluded a priori, and

5 now they've been included. So --

6 DR. WALLIS: Had it been included before

7 then the numbers would have been even bigger on that

8 notorious Figure 1.1?

9 DR. KIRK: I don't wish to get back to

10 1.1, but yes, yes they would have. So that's why

11 LOCAs are here, is they weren't included before. And

12 when you look at the, when you look at the fracture

13 driving force of the LOCAs relative to the secondary

14 size breaks, relative to everything else, there's no

15 question about it. They are the worst transient.

16 DR. SHACK: But it's not so much that they

17 weren't included before, it's they are just more

18 dominant because you've credited operator action which

19 has essentially reduced the importance --

20 DR. KIRK: That, as well. That, as well.

21 DR. SHACK: I mean that would be the

22 single biggest change, wouldn't it be?

23 MR. KOLACZKOWSKI: Well, let me point out

24 in the early work, again, a priori, the larger size

25 LOCAs were not even analyzed because at the time there

1 was experimental evidence that they interpreted meant
2 that you had to have considerable pressure for PTS to
3 occur and therefore in large LOCAs, when, you know,
4 very quickly get down to pressures of 100 pounds or
5 whatever, the a priori were not analyzed based on that
6 information.
7 We said, no, we're not going to start with
8 that premise. We're going to assume that, we were
9 getting evidence that was suggesting maybe the
10 pressure was not as important as perhaps previously
11 thought.
12 And so as a result we included medium and
13 large break LOCAs in the analysis. They have been
14 processed through the TH and the fracture mechanics
15 and low and behold we're finding out that indeed the
16 LOCAs and the larger size LOCAs are in fact a major
17 contributor to PTS challenge.
18 So in that case they were a priori not
19 analyzed.
20 MR. ROSEN: Even though the depressurized
21 the primary system to a large degree?
22 MR. KOLACZKOWSKI: Even though they
23 depressurized the primary system to a large.
24 DR. KIRK: And it's also, just as a side
25 note here, but I think relevant to the discussion

1 we're having, because we've, I mean the emergence of
2 medium and large LOCAs as important contributors is,
3 of course, a big change from the past, for reasons
4 we're discussing that it was excluded.
5 One of the things that, one of the many
6 things we've done to try to understand this is Terry
7 Dickson went back in the Oak Ridge archives and dusted
8 off a circa early 1990's version of a probabilistic
9 fracture mechanics code of the genre that was used in
10 the original assessments.
11 Put a large LOCA into it and found out
12 that it's predicting the same thing as we've got now,
13 that it's an important transient. So they weren't
14 there before simply because they were excluded, and
15 what Dr. Shack pointed out is also correct.
16 That previously other events, like
17 secondary side faults, the severity of those is
18 grossly over represented.
19 MR. ROSEN: So what we think we are at now
20 is a pressurized thermal shock problem with a little
21 P, big T.
22 MR. HACKETT: A bigger T than a P.
23 DR. BANERJEE: Is it mainly thermal stress
24 now? Well, what is the driver?
25 MR. HACKETT: The results would indicate

1 that this is somewhat akin to where we were, I know we
2 presented it to the Committee a number of years ago
3 the analysis in the BWR world, where you just had the
4 cold over pressure and thermal shock.
5 But that the thermal shock is, or the
6 thermal piece is more dominant than the pressure
7 piece, is what the results appear to be indicating.
8 DR. WALLIS: That figure you just
9 eliminated is a very nice one, with the green and the
10 red arrows. If you could put numbers on the range, it
11 would be very revealing. I think you'd find, as I
12 said before, that something like the flow, the change
13 in the flow analysis had a tremendous amount of
14 leverage.
15 The change in the treatment of TH always
16 had a relatively small affect. And maybe, you know,
17 if you had some numbers on here so we could see how
18 important these things are, rather than just have
19 green and red arrows.
20 MR. KOLACZKOWSKI: I guess I would just
21 say that I know some of the ongoing work is attempting
22 to do that. Some of it is hard to do. For instance,
23 if you take the second bullet, more refined binning.
24 I mean to try to put a number on, well,
25 they did ten bins, we did 150, what does that mean

1 numerically? That's hard to come at. Qualitatively
2 we know, we feel we've done a better job.
3 Because, as I said, we're not combining a
4 one turbine bypass valve scenario in with a main
5 steamline break. We've removed that conservatism.
6 Now exactly what that means in a quantifiable way, is
7 sometimes hard.
8 DR. SIU: And the short answer is yes. We
9 are certainly going to be looking at trying to
10 quantify that better. It's an important point.
11 DR. SHACK: I mean you want to quantify
12 the ones where there is uncertainty. And more refined
13 binning is good. You know, how good it is, is you
14 know, now operator action credit, you know, flaws --
15 MR. KOLACZKOWSKI: Yes, agreed.
16 DR. SHACK: -- those are things with
17 uncertainties and so when you take big credits for
18 them you'd sort of like to know just how much credit
19 you're really getting out of those things.
20 MR. KOLACZKOWSKI: Agreed. Okay, I think
21 we're at Step Five, I believe. Okay, so we did some
22 preliminary quantification, we do some binning. As I
23 pointed out, it was really a rather iterative process.
24 But we did take a point in the process,
25 once we had preliminary results available, that we

1 went back to each of the Licensees and presented the
2 results that we had in a preliminary, at this point in
3 the process, and allowed, not only them, but ourselves
4 to sort of stop, take a look at where we were and
5 essentially ask ourselves where could we be wrong?
6 What else should we look at? Should the
7 binning be changed? Do we have any inaccuracies in
8 the model? Maybe a dependency we haven't treated
9 right. Or maybe we grossly, in the Licensee's
10 opinion, over estimated or under estimated an operator
11 action credibility or whatever.
12 We gave them a chance to provide input to
13 us. We actually got formal comments from the
14 Licensees, and then responded to those comments
15 accordingly. So we took a point in the process to
16 stop and see where we were.
17 And, as I said, get the Licensees, as well
18 as our own chance to take a look at where we were and
19 whether we wanted to change anything. Models were
20 changed. Values were changed as a result of this
21 process. Next slide.
22 Then we did, based on the changes we made
23 to the model, changes we made to the value. Now we're
24 getting closer to the final results. I guess just a
25 word, a little bit about the uncertainty from the PRA

1 part is concerned.

2 And I know the Committee has seen a very

3 similar slide to this before. If you think about each

4 scenario, which is now, if you will, a TH bin, from

5 the PRA perspective it's treated as an interaction

6 really of three things.

7 You have some initiating event, and then

8 you have some series of mitigating equipment successes

9 and failures, like valves sticking open or not or

10 whatever. And then the operator perhaps does or does

11 not take certain actions.

12 From the PRA perspective, then,. the

13 frequency of the scenario is treated as the frequency

14 of the initiating event times the probability of the

15 equipment response times the probability of the

16 operator actions.

17 And each of those are treated essentially

18 as a random event. So the model, in it's 181,000

19 different scenarios are describing the randomness of

20 what can occur, in terms of what initiating event

21 might occur, and then what subsequent equipment and

22 operator responses might be.

23 So that's all captured in the model

24 development. And that aleatory aspect, the randomness

25 of what might occur and what could go wrong is really

1 handled, not in a number sense, but is handled in the
2 model by different scenarios in the model.
3 And that, hence, the reason why there is
4 181,000 different scenarios. For each scenario then
5 you have to develop a frequency. And those
6 frequencies are going to be summed together to
7 represent the frequency of a bin.
8 Now we're dealing with epistemic
9 uncertainties with regards to what is the actual
10 frequency, are ability to best estimate what the
11 frequency of that scenario is. And to capture those
12 epistemic uncertainties, we put distributions on the
13 frequency initiating event.
14 Distributions on the probability of the
15 different equipment responses. Distributions through
16 the elicitation process on the probabilities of the
17 operator actions. And essentially propagate those
18 through the entire model using Latin Hypercube
19 sampling techniques to come up with the distribution,
20 if you will, that's primarily capturing the epistemic
21 uncertainties with regards to what is the frequency of
22 each scenario.
23 DR. WALLIS: So when you hand something
24 over to the next the stage, which is the fracture
25 mechanics, you give them a whole set of these things

1 with the uncertainty distribution on each one? That's
2 a huge amount of information right there.
3 MR. KOLACZKOWSKI: That is correct. That
4 is correct. Next slide.
5 DR. BANERJEE: How do you choose the
6 distributions? Is there an empirical basis for this?
7
8 MR. KOLACZKOWSKI: Most of the
9 distributions came like from the data source that we
10 were using. Again, the first two plants, Oconee and
11 Beaver Valley, as I pointed out, use a generic data.
12 That's largely from NUREG/CR-5750, work
13 done by Idaho in which they developed not only mean
14 estimates of things like initiating event frequencies
15 and equipment failure and whatever, but also their
16 estimates on what the distribution should be.
17 Where there ought to a be a beta
18 distribution, a gamma, whatever. And what those
19 distributions were like. And that information is what
20 was used.
21 DR. SIU: Alan, if I can interject. It's
22 not that the distributions were necessarily chosen,
23 they are computed. They use the available
24 experiential data, using an aging estimation process.
25 Now you do have to choose a prior

1 distribution. In general, they use non-informative
2 prior distributions and then you simply update. And
3 so it's an algebraic process at that point.
4 Now at some point you generally try to
5 curve fit something that you can readily propagate
6 through the model, but that's a very minor correction
7 point.
8 DR. BANERJEE: How much data is there? I
9 mean for certain things there might be quite a bit of
10 data, but for others almost nothing, right? I mean
11 there aren't many situations where you have operator
12 actions under certain scenarios.
13 DR. SIU: That's right.
14 DR. BANERJEE: How do you choose those
15 distributions?
16 DR. SIU: Let me distinguish between the
17 two situations. In situations, obviously, where we
18 have equipment failures and we can go through the
19 process I talked about. In cases where you are doing
20 a direct elicitation, now again, it's not a matter of
21 choosing a distribution, per se.
22 You are asking the elicited experts what
23 is the likelihood that this probability is in this
24 range? So you can envision constructing a histogram,
25 basically. And then you can rough that in a

1 continuous curve to match that histogram or use the
2 histogram directly depending on however you want to
3 propagate that through the model.
4 So it's not a matter of choosing a
5 particular functional form and saying this is the
6 functional form a priori. You're trying to determine
7 what is the experts belief as to the value of that
8 variable.
9 What's the likelihood that that variable
10 takes on that value in this range?
11 DR. BANERJEE: So the expert's opinion
12 takes the place of data here?
13 DR. SIU: That's correct.
14 DR. BANERJEE: Okay. And then you do
15 whatever it is to find --
16 DR. SIU: That's correct. That's right.
17 The rest is, that's right. The rest is --
18 DR. BANERJEE: Is this procedure sort of
19 laid out in this Idaho report? Or is this something
20 that you've done with that data or expert's opinion in
21 the report?
22 DR. SIU: Well, there are lots of, I'm not
23 sure exactly the process Idaho used for things like
24 the LOCA break frequencies, but in general the
25 technology of expert elicitation, there are some

1 NUREG/CRs that we follow. One was written by
2 Professor --
3 MR. HACKETT: I was going to add, Nathan,
4 I think, just as an example, I think a point where
5 your question is going is you look at large break
6 LOCA. And, of course, there's not a lot of data on
7 large break LOCA. In fact, there isn't any.
8 Which is a good thing. And so you're
9 stuck in that kind of case with looking at things like
10 expert elicitation or precursors that may have led to
11 a large break LOCA under certain conditions.
12 And I think I can speak for just having
13 read that portion, especially NUREG/CR-5750, does go
14 into the assumptions that they made in that regard in
15 pretty good detail.
16 But in some cases, obviously, the data is
17 just not going to be there. You'd rather in every
18 case in this project where you had the data, that's
19 where you want to be. If you don't have the data,
20 you're then looking at statistical methods for
21 extrapolating or interpolating or you're looking at
22 precursors.
23 Or you're looking at expert elicitation,
24 sort of in a descending order as to, you know, where
25 you'd like to be.

1 DR. BANERJEE: The main concern is, of
2 course, that for the risk dominant sequences that you
3 have here, they are very rare events. And there is
4 not much data. And I don't know how you really
5 establish, with any confidence, the frequency for
6 these.
7 Or even for the initiating event, forget
8 everything else.
9 MR. HACKETT: It's very difficult. When
10 you look at the large break LOCA, that's just one
11 element of this project. But there's also other
12 efforts that the Research Office in NRR are pursuing.
13 They just had an expert elicitation panel
14 convene this week to look at that particular issue for
15 the reasons you cite. That's just a very difficult
16 scenario.
17 DR. BANERJEE: Well, to take an example,
18 who would have thought that these lines in the
19 Japanese BWR and the, you know, expert opinion is not
20 a great way to approach this maybe.
21 I don't know how you do it, but that
22 nobody ever thought of these scenarios that actually
23 occurred.
24 MR. HACKETT: Yeah, I think these are
25 weaknesses that are inherent in that type of process.

1 And in that kind of case I think Dr. Rosen's question
2 of earlier sort of, the fundamental situation of, you
3 know, how well do you do with what you don't know?
4 And of course you do the best you can, is
5 kind of what it comes down to. But in a number of
6 areas the most stark example for the NRC recently, of
7 course, is Davis-Besse.
8 And if we had all been sitting up here
9 talking to the Committee two years ago and somebody
10 were to have told myself or Dr. Shack or Ford that you
11 were going to eat through a six inch reactor vessel
12 head with boric acid corrosion, you probably would
13 have been in denial over that.
14 The model, you know, would not have
15 supported that type of view. So that's just
16 fundamentally where you're going of up against the
17 wall and you do the best you can.
18 DR. SIU: Ed, just to add one minor point
19 here, again. We talk about point estimates sometimes
20 and we treat the distribution as window dressing. But
21 in the LOCA frequency estimate in particular, there
22 are large uncertainties.
23 So what we're stating is our degree of
24 confidence in the LOCA frequency with which we use in
25 the analysis. And that frequency itself is a

1 representation, as Alan indicated, of random process.

2 So you're not saying with certainty the

3 event is going to occur, but here's a certain

4 probability it would occur in a time interval. And

5 we're highly uncertain about the governing parameter

6 of that process.

7 So, again, it's a statement of the

8 knowledge about that that we're trying to make. It's

9 not that we're really confident that the LOCA is going

10 to curve at a certain rate.

11 MR. ROSEN: I think the important point

12 about operator action on a LOCA has been made. Which

13 is the operators, in an expert elicitation, the

14 operators drill LOCAs ad nauseam.

15 And the response that they're required to

16 take is uniformly the same. Which is getting to $E_{zero}$,

17 which is the, which basically confirmed the reactor

18 has tripped, and allow the safety systems to do what

19 they're designed to do.

20 Monitor what's going on. There is not a

21 lot that they can do. So the issue is really all

22 about initiating a frequency. Well, how often is this

23 going to happen? And surely there, one doesn't know,

24 fortunately, because it hasn't.

25 And, but as to what the operators would do

1 if it did happen, I think we have a pretty good idea.
2 DR. WALLIS: Are you sure? Because one of
3 the problems with, the key problem with TMI, one of
4 them was that operators misdiagnosed what was
5 happening.
6 MR. ROSEN: That wasn't a LOCA.
7 DR. WALLIS: No, but they could have a
8 LOCA and for some reason that you don't know, they
9 could think it's something else. And this could be
10 because something else is happening in the plant
11 that's distracting or confusing them or something.
12 MR. ROSEN: I grant that, yes.
13 DR. WALLIS: This also happened at TMI,
14 several things went wrong simultaneously.
15 DR. SHACK: I think we're going to have to
16 move on here. We don't want to miss the chance to get
17 on the thermal hydraulics.
18 (Laughter.)
19 MR. KOLACZKOWSKI: We're almost there.
20 We're almost there.
21 MR. ROSEN: But they've only done a
22 hundred runs, so, here we've had 181,000 sequences.
23 DR. SHACK: I've got view graphs that
24 don't mention Oregon State at all.
25 MR. KOLACZKOWSKI: Okay, so anyway, a word

1 about the uncertainty analysis, again, a lot of the
2 aleatory, the randomness part is really handled by the
3 model construction.
4 Then we, to the best we can, put on
5 distributions with regards to all the inputs to the
6 sequences and then carry that through using Latin
7 Hypercube sampling through the model.
8 Step Seven, then ultimately is really
9 finalizing the results, doing all the final runs,
10 etcetera. And the only thing I wanted to point out
11 here is that, the point that was made earlier.
12 As we learned what was dominating, we went
13 back and did even better, finer jobs, finer binning,
14 whatever, on the stuff that was going to be important.
15 And as part of that process, those aleatory -- oh, the
16 slide before this one, I'm sorry.
17 Those aleatory uncertainties that were
18 coming up to be particularly important, not only did
19 we treat them in the model structure, but we also
20 tried to quantify those aleatory uncertainties.
21 And I've just list some of the more
22 important ones, where we actually tried to put numbers
23 on things that were, quote, random originally as put
24 in the model. And then we tried to associate a number
25 with the probability of that randomness.

1 What's the chance a LOCA would be a, if
2 you will, a small-small versus what's the chance it
3 would be at the larger end of the small break
4 spectrum. That kind of thing. Next slide.
5 And as it has already been pointed out by
6 Dr. Wallis. Dr. Wallis, yes, we, basically what you
7 get out of the end of this process is you have a bin
8 that is represented by a series of TH curves, pressure
9 temperature and heat transfer coefficient, primarily.
10 But also a lot of other information that
11 tags along with that. And you have a frequency of
12 that bin. And that frequency is described by a
13 histogram that comes out of taking all the epistemic
14 uncertainties, the distributions for all the inputs,
15 propagating them through the model and getting an
16 uncertainty on the frequency on the output.
17 And that was described in terms of
18 quantiles. All that information goes into the
19 fracture mechanics code, which ultimately is going to
20 take this frequency information, which again is not
21 just a mean or a point estimate, but actually a
22 distribution.
23 Multiply it ultimately by a conditional
24 probability of vessel failure, which is also going to
25 be a distribution, to get a distribution out on the

1 through-wall crack frequency.

2 DR. WALLIS: This is an amazing piece of

3 work. Now are you going to expect all the Licensees

4 to do the same thing?

5 MR. KOLACZKOWSKI: Well, I guess as was

6 already pointed out, if the rule is going to be able

7 to change as much as we think we might be able to, you

8 may get to the point where no Licensee will ever be

9 so, their vessels will not be challenged to the point

10 they'll really have to do anything.

11 If it does not turn out that way and the

12 Licensees would have to do some form of analysis, I'm

13 sure that the NRC, whether it be at this rigor or some

14 other, and I don't want to speak for the NRC.

15 But I imagine they'd say you've got to

16 address uncertainty somehow.

17 MR. ROSEN: Have you made reactor vessels

18 immortal?

19 (Laughter.)

20 MR. HACKETT: I wouldn't go that far. No,

21 I don't think so.

22 MR. KOLACZKOWSKI: No. Maybe they're good

23 to 60 years, I don't know if that means they are

24 immortal.

25 DR. BANERJEE: Until a through-wall crack

1 appears, I guess. Let me ask you, would this process
2 you've taken a thermal hydraulics curve which you
3 haven't moved up or down or put any uncertainties on.
4 The whole process of converting this into
5 through-wall crack frequency or whatever is highly
6 non-linear. Or apparently some of the correlations
7 look very non-linear to me. So, does it make sense to
8 do that?
9 I mean without actually putting the
10 uncertainty on and propagating it through the
11 non-linearity so you see whether it amplifies or
12 decreases or whatever.
13 MR. KOLACZKOWSKI: Well, I guess if you're
14 asking about the thermal hydraulic uncertainties, I'd
15 rather wait for the next part.
16 DR. BANERJEE: No, no, I'm saying the
17 process.
18 MR. KOLACZKOWSKI: Oh, the process.
19 DR. BANERJEE: I'm talking about the
20 process right now. What in detail the thermal
21 hydraulic uncertainties are is the second question.
22 But not taking it into account, let's say here where
23 there may be uncertainty of say 50 percent on the
24 number and the time rate of change of temperature,
25 maybe 100 percent. What effect does that have when

1 you put it through this process?

2 MR. KOLACZKOWSKI: Can somebody help me,

3 I'm still not understanding the question. I'm sorry.

4 DR. BANERJEE: Well, let's say that the

5 temperature that you get out of this calculation and

6 the rate of change of temperature has a large

7 uncertainty on it, which is distributed anyway you

8 like.

9 If you put this through this process, what

10 happens? Then it will contribute to the ultimate

11 uncertainty in the result, but will there be biases,

12 for example, if you average it because it's a

13 non-linear process?

14 So if you then average something and let's

15 say the fluctuation, let's just take a number and you

16 square it, the RMS is not zero, even though the

17 fluctuation can be zero. So any non-linearity gives

18 you this problem. So how do you handle that?

19 MR. KOLACZKOWSKI: Can somebody help

20 answer that?

21 MR. HACKETT: Dave?

22 DR. SIU: Let me, before Dave starts, let

23 me just take a crack at it because I'm not sure I

24 exactly understand either. But maybe it's down to the

25 time cut that you're taking here and --

1 DR. SHACK: I think the question is do
2 really hand them three curves or do you hand them a
3 good deal more information --
4 DR. SIU: Right, yeah, let me address that
5 a bit because I had some hand in developing the
6 uncertainty analysis approach. It's a very important
7 question, and when we briefed the Committee and
8 Subcommittee previously we said we were going to take
9 a good whack at some of these uncertainties, but there
10 were other things that we didn't think that we would
11 be able to do.
12 Ideally, you'd like to hand a band of
13 traces. Although, when you really try to do that
14 maybe even the image of a band isn't a very good
15 image, because the traces could develop quite
16 differently depending on how you vary your parameters.
17 But if you just visualize a set of traces,
18 yeah, you'd like to propagate that through. I think
19 Alan's earlier slide indicated we did a little bit of
20 that. We tried to identify what were key parameters
21 and we then developed deterministic traces for those
22 particular variations and assigned probabilities to
23 those particular traces.
24 So we went a little bit deeper than the
25 original bin definition and tried to create refined

1 bins to accommodate that. But I don't think we have
2 the full method here that says, yes, in principle we
3 will take this band and propagate it all the way
4 through.
5 Computationally, it would be a pretty
6 extensive task, but of course, that's not reason not
7 to do it. We just weren't able to in the scope of
8 this project.
9 MR. KOLACZKOWSKI: Again, if the thermal
10 hydraulic response for a scenario was, and again, it's
11 hard to quantify, but noticeably different from some
12 other bin we already had, one turbine bypass valve
13 stuck open versus four.
14 If the rate of cooling and/or the final
15 temperature we got to looked like it was starting to
16 be ten, 15, 20 degrees difference or something like
17 that, we said, well, let's don't keep these in one
18 bin.
19 Let's create another bin. And so now we
20 had a TH set of curves that represented the one TBV
21 case, and a different set of TH curves that
22 represented the four TBV case.
23 DR. WALLIS: I think that the uncertainty
24 that my colleague may be referring to is not how many
25 valves are stuck open, it's actually in the prediction

1 of the RELAP itself.

2 MR. KOLACZKOWSKI: Right, I understand,

3 yeah.

4 DR. SIU: The other thing I should of

5 mentioned, obviously, again, we've pointed out before,

6 we need to do some sensitivity analyses. We need to

7 better understand the results of this integrated

8 product that we're representing here.

9 So some of the things that we're talking

10 about clearly need to be pursued in the coming months.

11 DR. BANERJEE: I wouldn't be so concerned

12 if the conversion of this to the final result was a

13 linear process that would average out. I don't know

14 what the effect of the non-linearity is. That's what

15 concerns me. That can give you a bias in the average.

16 DR. SIU: And that's where again, without

17 necessarily carrying the full formalism of a

18 quantified analysis, sensitivity analysis should give

19 us some indication of the relative importance of that.

20 MR. BESSETTE: But the only way to really

21 get information on that is to run the results through

22 FAVOR. And that tells you, so you have, and every

23 time you run FAVOR, you run it with some specific

24 thermal hydraulic input, of course.

25 So, what you feed FAVOR as a series of

1 transients or a series of sensitivity studies of a
2 given transient through FAVOR, and you see how much
3 that effects, say, conditional probability of vessel
4 failure.
5 DR. BANERJEE: That would be fine. I mean
6 what you're suggesting is okay. I mean it would just
7 parametrize the rate of change of temperature or
8 temperature that you get out of these transients and
9 feed it in.
10 And it's not a, not a thermal hydraulic
11 calculation, it's just another FAVOR calculation.
12 MR. BESSETTE: That's right. So, in fact,
13 we're in the process of doing, we haven't completed
14 what we plan to do on that. We're planning to do a
15 number, taking a specific transient and doing a number
16 of perturbations on it, in order to understand better,
17 you know, ten degrees at this point in time is big or
18 small.
19 You've got to run these through FAVOR in
20 order to answer that question.
21 DR. SHACK: I mean, I thought that's what
22 Table 2.3 and 2.4 represented. We're doing that sort
23 of thing. You're saying that you haven't done those
24 runs yet.
25 MR. BESSETTE: Well, we have. See, we've

1 done thermal hydraulic sensitivity studies in the
2 sense that we've got a given thermal hydraulic bin,
3 let's say, as medium break LOCA.
4 And we vary, we go through a PIRT process
5 to decide what do we think is the most important
6 boundary condition, city analysis and physical
7 modeling in an analysis. So we've done these
8 sensitivity studies with RELAP so we feed, let's say,
9 30 RELAP calculations, that's 30 RELAP sensitivity
10 studies of a given transient.
11 We feed that through FAVOR and we generate
12 the distribution of conditional probability of vessel
13 failure. So, but we're still doing this RELAP
14 calculation.
15 DR. SHACK: Yeah, but I mean you assign
16 probabilities to those. So in affect you do end up
17 with a distribution. Now it maybe a crude
18 distribution, but it at least begins to answer the
19 question.
20 MR. BESSETTE: Correct.
21 DR. SHACK: So we've done that and we've
22 got those results, but we want to go a little bit
23 further. Well, I think you should at least take
24 credit for doing that. That's all I really wanted to
25 do.

1 DR. BANERJEE: That's what Dr. Siu was
2 saying.
3 DR. SHACK: Yeah, but I just want to make
4 sure that you've really done it.
5 MR. BESSETTE: Yeah, I thought that
6 impacts were, something more was being -- we wanted --
7 DR. BANERJEE: I want something more --
8 MR. BESSETTE: You want something more --
9 DR. BANERJEE: But it's a beginning.
10 MR. BESSETTE: Yes.
11 MR. KOLACZKOWSKI: I think we're done with
12 the PRA part.
13 MR. ROSEN: Well, I'm looking at the
14 agenda and I guess we're through Roman one and two,
15 which is the opening remarks and the introduction. I
16 don't know where we are on this agenda now.
17 DR. SHACK: Oh, we have problems with the
18 agenda, no question about it.
19 MR. HACKETT: We're most of the way
20 through the background at this point.
21 DR. WALLIS: We're going to collapse four.
22 MR. HACKETT: At least we think we are.
23 We were going to propose to collapse four and focus on
24 five. And at this point we'll turn it over to David
25 and Jack Rosenthal.

1 MR. ROSENTHAL: Yeah, let me just make an
2 introductory remark for the benefit of all the people
3 here. We did meet in December with the Thermal
4 Hydraulic Subcommittee, all day.
5 And presented a lot of developmental
6 assessment and took a lot of questions. And by the
7 end of that day an independent observer would have
8 been in dismay over what we, how well we were
9 portraying what we knew.
10 So we did do a little bit of regrouping.
11 One thing was that we had, as I say, just a large
12 amount of developmental assessment which that
13 Subcommittee was hearing for the first time. And we
14 decided we need to write a separate report which
15 people can really sit down and look at rather than
16 just seeing, you know, 150 slides or something in the
17 course of a day.
18 It's just an enormous amount of
19 information. The second thing is, and it's just the
20 way to go, we focused on where we had problems. Where
21 things weren't, where we weren't predicting results
22 well, rather than where we were.
23 That's the nature of the beast. And in
24 fact in a trial run with the, with my contractors, I
25 said, no, let's be very forthright and just show it

1 all. But I think that we left the Committee with the
2 wrong impression.
3 And, in fact, we can calculate downcomer
4 temperatures rather well. And that's what Dave is
5 going to present. So I just wanted to give that
6 perspective.
7 DR. WALLIS: Jack, the minutes of that
8 meeting show that we were reassured that everything
9 would become clearer on February the 5th.
10 (Laughter.)
11 MR. BESSETTE: So I just wanted to, so we
12 had this, one of the questions that was posed to us
13 was how good is RELAP? And not only how good is RELAP
14 by itself, but also the modeling approach which
15 depends upon RELAP for predicting the temperature at
16 a downcomer, which is potentially a multi-dimensional
17 problem.
18 Which is where the question of plumes
19 comes in. So we went through that on December 11th,
20 including we spent a few hours on the Oregon State
21 Program, and discussing the results and the CFD
22 analysis that was associated with that.
23 And I think it was, at least for me it was
24 fairly convincing combination of experimental results
25 and analysis. So the, so I was going to go over here

1 briefly --

2 DR. WALLIS: One of the things we learned,
3 I remember, was there's not just the downcomer, it's
4 actually, there's a lot of heating up of this cold ECC
5 water before it even gets to the downcomer. And that
6 made a big difference.

7 MR. BESSETTE: Yeah, that's right. It's,
8 you might say it was surprising. Previous
9 experimental programs didn't consider that aspect that
10 you actually get a lot of mixing before the ECC water
11 even gets into the cold leg curving in the injection
12 line. It's almost an amazing amount of mixing.

13 DR. BANERJEE: But is that a peculiarity
14 of the, well let's have a more generic issue here than
15 that. There were certain things that were shown in
16 the last meeting which we did not know was peculiar to
17 the experiment that was done or was something that
18 would happen in a full scale PWR.

19 And we suggested to you that you do some
20 CFD runs to see whether that would actually occur in
21 a full scale plant or not using the system that you
22 had set up. Because this was all single face flow.

23 And the mixing that you saw. Was that
24 done?

25 MR. BESSETTE: Let's say the work is in

1 progress. It's not done yet. We had to get
2 additional funding out and graduate students have to
3 be available. So between December 11th and now, no,
4 it's not done yet. But we are working on it.
5 DR. BANERJEE: So we have no assurance
6 that this is going to occur at full scale, the mixing
7 and the injection line which gave you most of the
8 credit.
9 MR. BESSETTE: Well, it's, except, well,
10 it was a focus on, when we're getting ready to do
11 Oregon State, it was one of the principle points of
12 focus for the scaling. So there was, it was looked
13 at.
14 The Froud number and the injection line
15 and the Reynolds number were looked at. And so the
16 injection, the size of the injection line and
17 injection velocity was scaled accordingly. So that
18 definitely was a point of focus on the scaling.
19 DR. BANERJEE: Well, maybe you should
20 explain the point, which is that they got an enormous
21 amount of credit, not for what was happening in the
22 reactor, but in the injection line itself.
23 The high pressure flow was sucking in cold
24 water from the cold leg and mixing it in the line. So
25 what was coming out was sort of a mixed flow. That

1 was the major source of mixing.

2 And because of that liquid coming in to

3 the pipe into which the HPSI was going in was almost

4 at the same temperature. So effectively the thermal

5 shock problem went away in some way because of the

6 mixing in the injection line itself.

7 MR. ROSEN: This is what, it could be very

8 cold water going in?

9 DR. BANERJEE: It could be very cold

10 water.

11 MR. ROSEN: And it mixes with the water in

12 the, existing water in the injection line which could

13 be, what? How hot?

14 MR. BESSETTE: So, yeah, they could be

15 dealing with 60 degree Fahrenheit water coming in and

16 mixing with, let's see, 400, 500 degree Fahrenheit

17 water.

18 DR. BANERJEE: But if that 400 degree

19 water doesn't, there's not an infinite amount of it.

20 I mean if there's no flow coming in of new 400 degree

21 water. A whole lot of things have to be right for

22 this to work.

23 DR. WALLIS: Yeah, well the thing is that

24 this has got to appear in some sort of -- I'm not

25 sure we can go into all of it today. It's clearly got

1 to be wrapped up somehow properly.

2 MR. BESSETTE: Yeah, so I hadn't planned

3 to go through all that again today. But I just wanted

4 to show you some selected assessment results from

5 RELAP.

6 DR. WALLIS: This thing that bothered me

7 about this thermal hydraulics is that the PRA guys

8 used some hydraulic information and it seems to be

9 somewhat of a moving reference point.

10 Because as OSU comes up with some new

11 discovery of how things mix, there's a different

12 thermal hydraulic condition which has got to be then

13 used by the PRA people. And yet they're are already

14 trying to make conclusions about plants based on the

15 old models which OSU is showing they are no longer,

16 not so good.

17 So are you really mature enough in your

18 thermal hydraulic analysis to give them what they

19 need?

20 MR. BESSETTE: Well, as I said, I mean,

21 along those lines, this whole question of mixing in a

22 sense, doesn't even arise with the risk dominate

23 sequences, which are fairly significantly sized LOCAs.

24 For these LOCA sequences basically

25 everything is at saturation. So we're not even

1 concerned about the potential existence of plumes.

2 DR. BANERJEE: So, I mean what you're

3 saying is the OSU experiments are totally unimportant

4 because they don't address the risk dominate

5 sequences. Is that what you're saying?

6 MR. BESSETTE: Well, the other way around,

7 if we hadn't done them it would be certainly a whole

8 other story. But as it turns out, yeah. It's, of

9 course when we, three or four years ago, we didn't

10 know large LOCAs were going to be risk dominate.

11 So we proceeded on the basis we had to

12 understand mixing, we had to make sure we understood

13 mixing well enough to ensure that the FAVOR approach

14 was appropriate.

15 DR. BANERJEE: Well, I think that there is

16 still the point that if the large scale plant is not

17 well portrayed by the OSU experiments then, and

18 because that is a possibility which maybe you can

19 eliminate with some CFD calculations.

20 Then it could still be that the plume does

21 not mix well in the large scale plant, and gives you

22 very, very different temperature gradient than a well

23 mixed assumption. So, I mean it's not completely

24 closed, that hole.

25 MR. BESSETTE: Yeah, so in fact, so in

1 fact one of your suggestions at the December meeting
2 was to do the full scale calculation where we take the
3 existing Oregon State CFD model and multiply the
4 diameter by seven and the length by four in order to
5 get the full scale.
6 DR. WALLIS: Expecting to see the same
7 answer.
8 MR. BESSETTE: You expect to see the same
9 answer, almost by definition.
10 DR. WALLIS: That sounds trivial. It's
11 like a homework problem, isn't it. Just multiply
12 these variables by four and see what happens. Or ten,
13 or whatever it is.
14 MR. BESSETTE: Yeah. But we're going to
15 do it anyway, just in case.
16 MR. HACKETT: Dave, why don't you try and
17 step through the slides and then we'll take any
18 questions as we go and hopefully elaborate where
19 needed.
20 MR. BESSETTE: Okay, so we use for all the
21 PTS analysis we've used the latest version of RELAP
22 3.2.2 .gamma. It was released in June of 6999. We
23 used the following models. The Oconee model dates
24 back to the original IPTS study and it's been updated
25 periodically.

1 Palisades we utilized a model. We didn't
2 have a RELAP model. We obtained a model that was
3 developed originally by Siemens and we modified that.
4 For Beaver Valley we took the existing HP
5 Robinson model, which again dates from the IPTS study.
6 And Westinghouse revised, substantially revised that
7 model to make it look like Beaver Valley rather than
8 Robinson.
9 We added a two-dimensional downcomer and
10 updated the treatment of boundary conditions and set
11 points and operating procedures. So we reviewed the,
12 we did, associated with the current effort, we did
13 some assessment of RELAP for PTS applications.
14 We went over everything, basically
15 everything we did at the December 11th meeting. We
16 looked at a variety of separate affects for integral
17 system tests. And I was going to show you today some
18 of the integral system test results.
19 DR. WALLIS: We might be able to make some
20 progress here. I mean we saw in December all the
21 curves and RELAP predictions versus experiments of
22 transients. Which were all very interesting, but
23 didn't really address the question of what's the
24 uncertainty as far as PTS is concerned.
25 And if you have a bottom line which says

1 you've now evaluated the uncertainties, then we don't
2 need to look at all the curves.
3 MR. BESSETTE: Well, so, yes, I'm only
4 going to show you a few curves. The bottom line that
5 you seek is only obtainable by feeding these results
6 through FAVOR.
7 DR. WALLIS: FAVOR takes the results and
8 calculates the uncertainties in the thermal
9 hydraulics?
10 MR. BESSETTE: In a sense, yes. But what
11 FAVOR does, it tells you if ten degrees is big or
12 small. Or, you know, half a megapascal is a bigger
13 small affect.
14 DR. WALLIS: It gives you the sensitivity.
15 MR. BESSETTE: It gives you the
16 sensitivities. Now, so, for example, if you're
17 predicting a 40 degree downcomer temperature you can
18 be off by 100 degrees and it doesn't matter in terms
19 of probability of failure.
20 But if you're at 200 degrees Fahrenheit,
21 perhaps ten degrees is important. And you don't know
22 that until you run the whole transient through FAVOR.
23 So that, be that as it may, I wanted to give you some
24 indication of stand alone, how well can RELAP predict
25 pressure and temperature.

1 I don't think there's ever been much of a
2 question about whether these codes can predict
3 pressure. From the first time I saw a comparison in
4 the 70's, it always does a good job on pressure.
5 The other key, one other key aspect to
6 these codes doing things well, and it all goes along
7 with predicting pressure. If you match, the first
8 thing you have to do to get good agreement is to match
9 your boundary conditions.
10 And they way you start by doing that is to
11 try to get an accurate prediction of a break flow.
12 And that, once you get that, you get the proper,
13 essentially you get a very good agreement of system
14 mass and energy. Next.
15 So I've picked out three integral system
16 test results to show you. I didn't pick these out
17 because they were the best ones, I just thought these
18 would be the databases that exist for MIST and ROSA
19 and so on.
20 These seemed to be the most appropriate
21 tests to look at. This is a 4.4 inch break from MIST.
22 MIST is an integral test facility configured to look
23 like a B&W plant. On the left is a comparison of the
24 RELAP predicted temperature and the experimental
25 temperature.

1 And black is RELAP and the red is that
2 data.
3 DR. RANSOM: Where is this temperature?
4 MR. BESSETTE: This is downcomer
5 temperature.
6 DR. RANSOM: Where? Down the beltline?
7 MR. BESSETTE: It's in the beltline, yeah.
8 Now, of course viewing the experimental facilities and
9 so you always have limitations. MIST unidowncomer,
10 external downcomer.
11 So in MIST you only expect to see
12 basically a single temperature. But, in that sense,
13 you know, you can see RELAP has done, what I consider,
14 excellent job of --
15 DR. BANERJEE: What's the difference in
16 the rate of change of temperature with time? Because
17 that's one of the main concerns, right?
18 MR. BESSETTE: That's why, well, so
19 that's, in fact, what I mean is that you have to look
20 very carefully at these results in terms of are they
21 important for vessel failure or not?
22 And the only way you can tell if a rate of
23 change of temperature is important or not is when is
24 it occurring?
25 DR. BANERJEE: So let's say you took the

1 data around 3,000 seconds at 2500. The experimental
2 data shows you, and this is typical of many runs in
3 ROSA IV. That the rate of change of temperature is
4 much higher than predicted by RELAP.
5 In fact, if red is the experimental data.
6 And I notice that in most of the other data that
7 you've shown previously. So how important is the rate
8 of change compared to getting the temperature roughly
9 right?
10 MR. BESSETTE: Well, you have to know
11 both. Because certainly the -- you have to know the
12 absolute temperature, because that's giving you like
13 the fracture toughness.
14 DR. BANERJEE: Right. And then it's the
15 rate of change.
16 MR. BESSETTE: The rate of change is
17 giving it a thermal --
18 DR. BANERJEE: In fact, we left a question
19 open as to the trying to understand the relative
20 importance of these and these transients. Because the
21 rate of change was not well predicted.
22 MR. BESSETTE: I don't know if I'd go as
23 far to say as not well predicted.
24 DR. BANERJEE: Well, it's a factor of two,
25 sometimes three. I don't know what the number is.

1 DR. WALLIS: Well, it's a factor of about
2 five or more if they are around 200 degrees
3 Fahrenheit.
4 DR. BANERJEE: It may well not be
5 important, but we need to know that.
6 MR. HACKETT: I think there are pieces
7 here that are separable. It appears what David was
8 prepared to do was to assess how well the code works
9 in predicting temperature and rate of change of
10 temperature versus an experiment.
11 And you're asking the much more difficult
12 question. It's a real good question. Is what do
13 those rate of changes, for instance, do when you get
14 into the non-linearities and the FAVOR code.
15 And I think the short answer to that
16 question is they could be significant. And I think we
17 have more work to do in that area. We may not --
18 DR. WALLIS: We may not need
19 non-linearities if it's rate of change of temperature
20 that matters. I mean if it's bigger it may,
21 non-linearity or not, it may produce a bigger thermal
22 stress.
23 MR. HACKETT: Correct, correct.
24 DR. WALLIS: So that was the question we
25 had in December. Was you can show us all these

1 curves, but how do you extract from them what really
2 is going to have an influence on the PTS answer.
3 MR. HACKETT: I think the only way you get
4 there is exactly as David said. We need, we have some
5 more work to do with FAVOR. An additional FAVOR runs
6 in terms of some sensitivity studies.
7 I think Dr. Shack characterized it
8 correctly is that we run some of these to the point
9 that we have, you know, a certain level of confidence
10 in what we've done to put forward a tech basis, but
11 it's not to say we don't have more work to do.
12 And this is a very good case in point of
13 where we've got some more work to do.
14 DR. BANERJEE: We came back in December
15 and said that obviously there's going to be an
16 uncertainty in the predictions with RELAP. This needs
17 to be quantified and hopefully University of Maryland
18 or some other organization was doing that, looking at
19 the comparison systematically between RELAP and the
20 experiments, quantifying the uncertainty, trying to
21 understand what in fact that has on all these sort of
22 results that are coming out.
23 Now, we haven't seen the uncertainty
24 analysis yet. We were, in fact, one of the points we
25 made is that we wanted to have that at this meeting.