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Materials and Metallurgy Subcommittee

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS (ACRS)

SUBCOMMITTEE ON MATERIALS AND METALLURGY

+ + + + +

TUESDAY

JANUARY 15, 2002

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ROCKVILLE, MARYLAND

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The Subcommittee met at the Nuclear Regulatory Commission, Two White Flint North, T2B3, 11545 Rockville Pike, at 8:30 a.m., F. Peter Ford, Chairman, presiding.

COMMITTEE MEMBERS:

F. PETER FORD, Chairman, ACRS, Member

MARIO V. BONACA, ACRS, Member

WILLIAM J. SHACK, Member, ACRS

STAFF PRESENT:

NOEL F. DUDLEY, ACRS Staff Engineer

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1     ALSO PRESENT:

2             EDWIN HACKETT

3             MICHAEL MAYFIELD

4             MARK KIRK

5             ROY WOODS

6             DAVID BESSETTE

7             ALAN KOLACZKOWSKI

8             ALI MOSLEH

9             FRED SIMONEN (on the phone)

10            TERRY DICKSON

11            BRUCE BISHOP

12            SHAH MALIK

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

(8:37 a.m.)

CHAIRMAN FORD: The meeting will now come to order. This is a meeting of the ACRS Subcommittee on Materials and Metallurgy. I am Peter Ford, Chairman of the Materials and Metallurgy Subcommittee. The other ACRS Members in attendance are: Mario Bonaca, William Shack, and Graham Wallis will be here at lunch time.

The purpose of this meeting is for the Subcommittee to review the status of the Pressurized Thermal Shock Technical Basis Reevaluation Project. In particular, the staff will present the initial results of the reactor vessel failure frequency of Oconee Unit 1 as calculated by the FAVOR (Fatigue Assessment of Vessels - Oak Ridge) probabilistic fracture mechanics code.

The Subcommittee will gather information, analyze relevant issues and facts, and formulate proposed positions and actions, as appropriate, for deliberation by the full Committee at the next meeting in February.

Mr. Noel Dudley is the Cognizant ACRS Staff Engineer for this meeting. The rules for participation in today's meeting have been announced

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1 as part of the notice of this meeting previously  
2 published in the Federal Register on December 19,  
3 2001.

4 A transcript of this meeting is being  
5 kept, and will be made available as stated in the  
6 Federal Register Notice. In addition, a telephone  
7 bridge has been set up to allow individuals outside  
8 the meeting room to listen to the proceedings.

9 It is requested that the speakers first  
10 identify themselves and speak with sufficient clarity  
11 and volume so that they can be readily heard. We have  
12 received no written comments or requests for time to  
13 make oral statements from members of the Public.

14 The staff briefed ACRS Subcommittees on  
15 the PTS Reevaluation Project in March, April, and  
16 September 2000, and in January and July 2001. The  
17 ACRS commented on the PTS Reevaluation Project in a  
18 letter dated October 12, 2000.

19 In this letter, the ACRS stated that the  
20 Project was well thought out and recommended that the  
21 staff examine the implications of using a large early  
22 release frequency (LERF) acceptance guideline based on  
23 an air-oxidation source term on the acceptance value  
24 for reactor pressure vessel failure frequency.

25 The staff has issued SECY papers

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1 concerning the following:

- 2       ° development of the current PTS screening  
3 criterion and the motivation for reevaluating  
4 the criterion;
- 5       ° identification of PTS scenarios and estimates  
6 of their frequency, thermal hydraulic boundary  
7 conditions for the fracture mechanics analysis  
8 of the reactor vessel, and the probability of  
9 thru-wall cracks; and
- 10       ° identification of key inputs to the  
11 probabilistic fracture mechanics analyses, such  
12 as, generalized flaw distribution, neutron  
13 fluence, fracture toughness models and  
14 embrittlement correlations, FAVOR code  
15 development and the associated verification and  
16 validation process, and calculation of PTS  
17 thru-wall crack frequency.

18               We will now proceed with the meeting and  
19 I call upon Mr. Michael Mayfield, of the Office of  
20 Nuclear Reactor Regulations, to being.

21               MR. MAYFIELD: Good morning. Staff has  
22 come today, as Dr. Ford has suggested, to present a  
23 briefing, a fairly detailed briefing as you can tell  
24 by the size of the package, on the work on pressurized  
25 thermal shock and reevaluation of the technical basis

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1 for the PTS rule.

2 We have appreciated the time and effort  
3 that the ACRS as a full committee and this  
4 subcommittee in particular has invested over the last  
5 year or two in supporting this activity. We have  
6 taken this on as a major effort within the Office of  
7 Research and we think it is providing some direction  
8 for future risk informed activities for rules like  
9 PTS.

10 The uncertainty analysis has been a big  
11 piece of what we've been trying to do. Professor  
12 Apostolakis had asked us to present an example where  
13 we walked all the way through the work and through the  
14 uncertainty analysis.

15 One of the things the staff is prepared to  
16 present to you at this meeting is an example of how it  
17 all goes together. We have some preliminary results  
18 from the Oconee plant and then we'll use those to  
19 provide an example of how the whole analysis goes  
20 together and hopefully clarify what we've been  
21 promising to come tell you about for some time now.

22 With that I would like to turn it over to,  
23 I guess, Mark Kirk or Ed Hackett to open the briefing.  
24 We hope that we'll satisfy your interest, at least for  
25 today.

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1 MR. HACKETT: Thanks, Mike. We have quite  
2 a team arrayed here to do this briefing. To my right  
3 is Alan Kolaczowski. My name is Ed Hackett. I'm  
4 Assistant Chief of the Materials Branch in the Office  
5 of Research. Mark Kirk, Shah Malik, and Dave Bessette  
6 are over here to my left and there will be others  
7 coming.

8 I guess a couple of items of  
9 administrative business. On your schedule if you have  
10 that in front of you, we are proposing at this point  
11 swapping Roman numerals III and IV. After this status  
12 briefing, which will be largely a combination of  
13 myself, Mark Kirk, and Alan Kolaczowski, we will go  
14 into the modeling process before we get into Ocone  
15 specific results.

16 Also, I know, as the Chairman mentioned at  
17 the opening of the meeting, there are a number of  
18 people joining us on the phone line. To allow  
19 opportunity for more to join in, we are not going to  
20 identify the folks on the phone line until the break.  
21 At the break point we will take some time to ask you  
22 to identify yourselves.

23 At this point, also I guess I should  
24 mention the purpose of this brief is -- I guess we  
25 could go to the first slide, Mark -- is a status

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1 briefing. At this point we are not looking at  
2 requesting a letter from the committee. Obviously if  
3 you feel a letter is necessary for some reason, that's  
4 a different story but we are not coming requesting a  
5 letter in any specific fashion on the project.

6 I guess it is unfortunate, as Mike  
7 mentioned, a lot of this particular meeting was driven  
8 by Professor Apostolakis. We will miss him today but  
9 I'm sure he will make sure that whatever is presented  
10 today we will be taken to task for -- well, we will be  
11 compounding with Professor Apostolakis at some point.  
12 He was a key driving force behind wanting to see us  
13 step through the uncertainty process. We will miss  
14 him today.

15 That's going down the list of meeting  
16 objectives that you see here. That's a key part of  
17 the meeting today to describe the modeling process and  
18 the treatment of uncertainty. Major departure from  
19 what we've done in the past for those of you who are  
20 familiar with this rule, 10 CFR 50.61.

21 The PTS rule is a rule that is basically  
22 keyed towards the best estimate approach and there are  
23 margins added to account for uncertainties in rather  
24 a crude fashion compared to what we think we can do  
25 today. One of the key goals in this project, which is

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1 at least two to three years into the tech evaluation  
2 at this point, was to try and treat those as we went  
3 along.

4 I think I can say it is the most  
5 comprehensive treatment we've ever done in this  
6 technical area. However, I think it would be fair up  
7 front to point out that what you will see is the  
8 uncertainty treatment has also been done on I guess I  
9 would say not an equal basis.

10 There will be some elements of the project  
11 where you will see uncertainty treated about as well  
12 as we know how to do. Then there are other areas  
13 where we weren't able to do as well for any variety of  
14 reasons. In a lot of cases lack of data or lack of  
15 appropriate data. You'll see that as we go through  
16 the day and a half here.

17 Also, at the end of the status briefing  
18 I'll try and leave you with our bottom line so you  
19 don't make everyone here wait a day and a half to see  
20 where we're going.

21 The Chairman mentioned the other big part  
22 of the brief is to discuss current results and  
23 insights from the analysis of the Oconee plant which  
24 was one of four that we're doing in the project for  
25 the tech bases and provide one detailed example of the

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1 modeling in the uncertainty process.

2 With that, I guess we'll move on to the  
3 basic overview slide of project status. The graphic  
4 gives you really the three pieces that have gone into  
5 this in terms of the technical or scientific areas.  
6 PRA events, sequence analysis is basically the  
7 beginning part.

8 The thermal hydraulic analyses to describe  
9 in detail the transients and then the integrating  
10 piece which is the probabilistic fracture mechanics  
11 analysis, No. 3 up there and ultimately going down to  
12 yielding a yearly frequency thru-wall cracking which  
13 is the way the previous rule was also set up.

14 This is the way we set up the project for  
15 the technical evaluation so we have developed an  
16 approach to do that. That is described in the  
17 graphic. I think I basically said everything under  
18 the second bullet.

19 Most recent accomplishments include the  
20 finalization -- maybe I shouldn't use finalization.  
21 The FAVOR code is now a working code that includes  
22 what we think are all the updates that were necessary  
23 to start the runs.

24 That was completed largely thanks to some  
25 pretty heroic efforts on the part of the Oak Ridge

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1 National Laboratory, most notably Terry Dickson and  
2 Richard Bass and then Paul Williams. That was  
3 released to the public as version 1.0 in October.  
4 There will be, no doubt, refinements and enhancements  
5 as we go along. That was a major piece to enable the  
6 rest of this.

7 We are estimating the risk of vessel  
8 failure for four plants and attempting to generalize  
9 from there. We have two combustion engineering  
10 plants, one Westinghouse plant, and one BNW plant that  
11 you can see listed there.

12 Right now the Oconee analysis is pretty  
13 much in a draft form. It has been completed to a  
14 draft state in all the technical areas complete with  
15 an estimation of the thru-wall cracking frequency that  
16 is a draft of preliminary effort at this point that  
17 we'll describe.

18 The other three plants you can see their  
19 status there. We have in a lot of cases, I guess I  
20 should mention, the licensees in the industry have  
21 been a very key part of this effort. A lot of the  
22 inputs on the PRAs and the thermal hydraulic inputs  
23 were from the licensees in the industry on a volunteer  
24 basis.

25 This has been -- the project couldn't have

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1 been done without that type of assistance. A lot of  
2 credit is due to the industry participants. Bob Hardy  
3 this year had three reactor vessel integrity groups  
4 within the Materials Reliability project. That has  
5 been extremely beneficial cooperation along the way  
6 for us. That is the overall status of the project  
7 right now.

8 We are on schedule to complete the  
9 technical basis. We are looking at a schedule to  
10 complete the technical basis in 2002. Hopefully we  
11 would be looking at embarking on rulemaking somewhere  
12 after that.

13 Work remaining, on the next slide. We  
14 have discussed some of this with the committee  
15 previously. A fairly major effort underway on Q/A  
16 that is pervasive to the project. That has been  
17 underway simultaneous with the technical effort most  
18 of the way. A particularly large effort they are  
19 devoted to Q/A of the FAVOR code, validation and  
20 verification of the FAVOR code.

21 Finishing the internal events analyses for  
22 the four plants, that will hopefully complete in the  
23 first half of this year and then we'll have a fair bit  
24 of integration to do to go from there.

25 Another element we could spend a few

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1 minutes discussing I will come to in a minute and show  
2 you that the results for the Oconee plant are going  
3 the way we had hoped that the project would go. The  
4 risk is looking like it is less than expected, or less  
5 than we had looked at in the past.

6 One of the things that was a factor in the  
7 project -- Nathan Siu couldn't join us today  
8 unfortunately but Nathan was one to flag up early to  
9 the working staff on the project and also to the ACRS.  
10 The notion of external event risk contribution has not  
11 really been addressed previously in PTS evaluations  
12 largely because the internal events dominate so  
13 dramatically.

14 In this case it's looking like that risk  
15 number is coming down low enough that I think we will  
16 have to be considering external events. We have  
17 initiated work in that area but that is something we  
18 have not embarked upon before so that is a bit of a  
19 departure for us in terms of that effort.

20 Under that we're talking about things like  
21 fires, for instance, natural hazards and how they may  
22 contribute either in tandem or singly with some of the  
23 PTS initiators. That is something we will spend at  
24 least a little bit of time discussing today, too.

25 Then there is the overall integration of

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1 the results and the risk criteria. Those of you who  
2 have followed this project know that the regulatory  
3 guide on the plant specific analysis which is  
4 regulatory guide 1.154 is really key to a risk  
5 criterion of 5E-6.

6 We are not coming here to discuss that  
7 today. That will be the subject of a separate  
8 meeting. We are in the process led by the PRA branch  
9 working on a SECY paper that will outline the staff's  
10 approach to what that risk criteria should be.

11 I guess in short right now it's not clear  
12 that will stay at 5E-6 or move to some other number in  
13 that range. That remains to be determined and will be  
14 the subject of the SECY paper and some potential  
15 discussion debate with the commission itself. There  
16 is some work that remains.

17 CHAIRMAN FORD: If I could ask a couple of  
18 questions. In some of the earlier correspondence on  
19 this whole reevaluation project. Mention was made of  
20 the continuant and that it would not be covered in the  
21 current work scope, the current paid for budgeted work  
22 scope.

23 Since you are coming to the end of the  
24 project by the end of this year, do you have any  
25 thoughts as to where you stand on this or are we going

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1 to lure the frequency down to E-6?

2 MR. HACKETT: These are really good  
3 questions, Peter. As you know, they have been the  
4 subject of a lot of debate. I'm probably not the --  
5 Nathan Siu would probably be the most qualified person  
6 on the staff to get into that, Nathan or Mark  
7 Cunningham.

8 Since they weren't able to be here with us  
9 today, the staff's current thinking on that is to stay  
10 nominally with the criteria that exist at the moment  
11 which is a CDF based approach. Also based on, as  
12 we'll get into extensively today,  $RT_{NDT}$  as  $RT_{NDT}$  is an  
13 index.

14 At least the staff's thinking going into  
15 this is we will retain those features. As you  
16 mentioned, we are pretty late in the game to be  
17 looking at changing horses significantly, but that  
18 will remain an effort to outline in the SECY paper.

19 When Nathan put together an outline, this  
20 is vintage about November of 2001, we were looking at  
21 pursuing several options. One of them would have had  
22 a departure that would have included addressing LERF  
23 and containment integrity.

24 We at this point would be -- I think I can  
25 speak for maybe myself and a few others here -- not

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1 looking at pursuing that path right now as a  
2 recommendation, but that remains to be debated at  
3 higher levels. Obviously it's not my decision as to  
4 how we go forward with that.

5 Or it may be that we go forward with a  
6 version that is RT<sub>NDT</sub> CDF base now and continue work  
7 looking at the LERF element and see if it's warranted  
8 that we make a change to the rule in the future along  
9 those lines. I think that is the way I would answer  
10 it. I don't know if anybody else has anything they  
11 would like to add to that.

12 CHAIRMAN FORD: Actually, you're an ideal  
13 feed man because the other question I had was related  
14 to you mentioned what's going to happen in the future  
15 on the regulation point of view.

16 Given the fact that two of your reactors  
17 that you've got on your study, Palisades and Beaver  
18 Creek, if you are using the current screen criteria,  
19 you've only got a couple of degrees, 1 degree, 2  
20 degrees difference between RTPTS and current screening  
21 criteria. Those problems for those particular  
22 reactors are very current.

23 Ford Calhoun coming up for a license  
24 renewal is also very close and that's this year. What  
25 is the timing? You say that this is going to end.

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1 The technical part is going to end this year and then  
2 you are going to some sort of regulatory discussions.

3 MR. HACKETT: Right.

4 CHAIRMAN FORD: Is there a lack of urgency  
5 here?

6 MR. HACKETT: There is in all fairness  
7 less than there was. There was a time when we started  
8 this project where it was to a large degree being  
9 driven by a number of events, a number of things  
10 involving the technical accomplishments that have made  
11 it possible is one thing.

12 But also being driven by a lot of the  
13 events at the Palisades plant where at one time -- I  
14 think that maybe representatives from Palisades are  
15 here on the line -- at one time their PTS screening  
16 criteria date looked like it was going to be in the  
17 range of 2003/2004.

18 They have since made submittals to NRR  
19 that have taken them, my understanding is, to 2011 and  
20 those were largely arguments based on fluence and  
21 dosimetry is my understanding. That urgency went away  
22 to that degree.

23 However, you raise a key point that there  
24 is still a fair bit of urgency in this project  
25 because, as you mentioned, people are making decisions

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1 for their plant's futures based on, in large part,  
2 whether or not they are going to have a viable reactor  
3 vessel for that renewal period.

4 Those decisions are very here and now so  
5 we take that very seriously from a schedule  
6 perspective. But to go further, the technical basis  
7 we are anticipating completing in 2002 the idea is we  
8 would start a rulemaking process in parallel with  
9 that. That would be Cindy Carpenter's branch in NRR  
10 and they have prepared resources for 2002/2003 time  
11 frame to undertake rulemaking in this area.

12 Again, schedule impact can be critical  
13 because we are probably talking a rulemaking that is  
14 two years in the doing. That would be from, say, this  
15 fall. We would be into 2004/2005 time frame before we  
16 would have a rule that would be on the books in 10  
17 CFR.

18 In the meantime, hopefully the technical  
19 basis would be there so that people could feel  
20 encouraged that it's going a certain way. It's a  
21 little premature now to say just based on the results  
22 from one plant that everything is going to come up  
23 nice and rosy. At the moment that's the way it's  
24 heading.

25 MR. MAYFIELD: This is Mike Mayfield. I

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1 think it's worth pointing out that while indeed there  
2 are some fact-of-life changes that have happened with  
3 some of the plants that maybe take some pressure off,  
4 there still remains significant interest from, at  
5 least, at the office level.

6 Ashok Thadani is keenly interested in this  
7 rule or this activity and making sure that it stays on  
8 track. That part of the pressure has not gone away.  
9 He is focused on it. Some key members of the project  
10 team did get distracted from some of the staff's  
11 efforts dealing with the September 11 events. We are  
12 working to try and recover from that.

13 There was an impact that we are trying to  
14 deal with now. Mr. Thadani and Mr. Zimmerman remain  
15 focused on this rule and keeping it on the schedule,  
16 at least as much as we possibly can.

17 MR. HACKETT: I guess with that we'll flip  
18 to the bottom line. This is after a day-and-a-half  
19 worth of presentation tomorrow what we will come to.  
20 We just thought we would hit you with that up front to  
21 let you know what's coming. We ended up in a lot of  
22 debate over how to present this so it's a work in  
23 progress. It does say preliminary on it and I would  
24 encourage people to take that seriously.

25 The current risk criteria from the

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1 regulatory guide set at 5E-6. You also see two curves  
2 on there that describe the results of the project for  
3 Ocone that are basically looking at the RTPTS versus  
4 the thru-wall cracking frequency where you have two  
5 key junctures.

6 You're looking at it after 40 years of  
7 operation and then you're looking at it if you were to  
8 project ahead to the actual screening limits where  
9 they are set now, 270 and 300.

10 What you can see over on the left-hand  
11 side there is that some pretty exciting results here.  
12 Approximately 4 orders of magnitude lower than the  
13 nominal risk criterion after 40 years of operation and  
14 2 orders of magnitude lower at the current screening  
15 limits.

16 This is a pretty exciting result for us.  
17 Again, we are hoping this holds as we go through some  
18 more advanced and refined Q/A of the codes and the  
19 data that produce this result. You will hear a lot  
20 about that and the propagation and uncertainty as it  
21 goes through this analysis.

22 I wanted to get this to you up front  
23 because this is what we went into the project hoping  
24 would be the case. Philosophically the idea was that  
25 there were a lot of conservatisms, or at least

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1 significant conservatisms embedded in the current rule  
2 and that with the aid of more accurate analyses and  
3 evaluations we would hopefully be able to remove some  
4 of that.

5 I guess what I would leave you just for  
6 this opening is it does look like it's going in that  
7 direction right now so we are pretty happy with that  
8 result.

9 PARTICIPANT: Where is 60-year life?

10 MR. KIRK: It's the next dot up.

11 CHAIRMAN FORD: Bill, he's off the  
12 computer -- the microphone. What was the answer to  
13 that?

14 MR. KIRK: The answer is it's the next dot  
15 above 40.

16 MEMBER BONACA: Okay. So just above one.

17 MR. KIRK: Not much further up.

18 CHAIRMAN FORD: I see. And you mentioned  
19 that obviously this is because of excessive  
20 conservatisms in the current code. Does it turn out  
21 to be one significant conservatism?

22 MR. HACKETT: You're a good straight man.  
23 The next slide is our attempt to go into that.

24 MR. KIRK: Should I give him the \$20 now?

25 MR. HACKETT: Wait. We debated this one

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1 a lot, too. That question has occurred to a lot of  
2 folks as we've been through this. What is the key  
3 driver for this? In the past it has been for the PFM  
4 inputs, the flaw density, and distribution. That has  
5 been a key driver.

6 But I think at this point we are not able  
7 to say exactly in terms of quantitative assessment X  
8 percentage came from this area, X percentage came from  
9 another area. We will hopefully get to that point.

10 What we tried to do on this slide is just  
11 show you the trends and sort of how they hit here with  
12 the green arrows showing items that would tend to  
13 reduce the conservatism or decrease the risk, and the  
14 red arrows showing areas that might be or would be  
15 tending to increase the risk.

16 The only three upward arrows on here are  
17 acts under PRA. Acts of commission that were  
18 considered were operators did the wrong thing at the  
19 wrong time, external events, when they are considered,  
20 would obviously increase the risk over all. We have  
21 not gotten into that to any significant degree yet.

22 Some nonconservatisms removed in the  
23 arrest and embrittlement models also have a slight  
24 upward trend there, too. But many more down arrows,  
25 down green arrows here than there are the upward red

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1 arrows. The overall effect on the project has been to  
2 reduce the risk and the conservatism.

3 Let's see where I wanted to focus here.  
4 PRA I think, and Alan will get into this, a lot of the  
5 PRA effort goes into much more refined binning. Alan  
6 will talk about that in detail. The previous binning  
7 of some of the event sequences was much greater than  
8 has been done in this project. That has been a major  
9 improvement.

10 Under PFM there was a significant  
11 conservative bias in the toughness model that has been  
12 removed or mitigated. Most of the flaws now we find,  
13 and this goes with expectation from some of our  
14 experimental work, the flaws are embedded. They are  
15 not surface breaking. In fact, we have not seen  
16 surface breaking flaws in the actual experimental  
17 evaluations we've done from real vessel materials.  
18 That's been a big factor.

19 Also, and you'll see details of this, we  
20 are now looking at spacial variations of the fluence  
21 where as before we assumed that all the materials were  
22 at the maximum fluence and the vessel was made of the  
23 most brittle material. Now we are considering the  
24 spacial map in the vessel belt line region. That is  
25 a significant aid.

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1 I guess with that --

2 MEMBER SHACK: On the thermal hydraulic  
3 sequences, is that just basically the binning again?  
4 You are not assuming that all the horrendous thermal  
5 hydraulic events?

6 MR. HACKETT: Right. I think largely,  
7 Bill, it's mainly binning that has been the  
8 improvement there. Dave?

9 MR. BESSETTE: I think that's right.  
10 There hasn't been that much change and the way we  
11 predict these transients is the fact that we can do a  
12 lot more sequences than we could 15 years ago.

13 MEMBER BONACA: What are you talking  
14 about? Operator action credited in the sequences, you  
15 mean?

16 MR. BESSETTE: Yes. We ran sequences in  
17 which the operator action is credited and that makes  
18 a big difference a great deal of the time.

19 MR. HACKETT: That's one I should have  
20 highlighted, too. Dr. Bonaca raises a good point,  
21 especially for Oconee which is a BNW plant. With the  
22 one steam generators there were the previous sequences  
23 that, I don't want to say dominated, but were very  
24 significant which included things like main steam line  
25 break and steam generator two rupture.

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1 By virtue largely of crediting operator  
2 actions much more significantly, you'll see when Alan  
3 goes through his presentation that those have come way  
4 down in terms of contributors to PTS. That has been  
5 another major improvement.

6 MEMBER BONACA: And you will discuss the  
7 uncertainties later on.

8 MR. HACKETT: Yes.

9 MEMBER BONACA: We'll have a feeling for  
10 what dominates uncertainty here if you have some  
11 specific --

12 MR. HACKETT: Specific transients and  
13 sequences.

14 MEMBER BONACA: Specific elements of this.  
15 You are showing us improvements and, one that is in my  
16 mind, what is driving uncertainty more than other  
17 things. I mention, for example, further action would  
18 drive uncertainty.

19 MEMBER SHACK: They only gave us point  
20 estimates before. Presumably we are going to see  
21 uncertainty bands.

22 MEMBER BONACA: I understand that.

23 CHAIRMAN FORD: Ed, could you go back to  
24 the previous graft? It's more for my edification.  
25 Thanks.

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1           There's another way of looking at it that  
2 if you want to decrease the cracking frequency down to  
3 10 to the -6 taking into account uncertainties on the  
4 containment. Is another way of looking at it you  
5 could just go to extreme criterion way up at 300? I'm  
6 just eyeballing this thing. 300 or 350 or 375?

7           MR. KIRK: Where you -- well, how we take  
8 this information and turn it into a screening criteria  
9 will be an interesting piece of technical work. At  
10 least in looking at it this way, let's be clear that  
11 reflects an assumption that we would intend to look at  
12 it this way.

13           Looking at some materials based value on  
14 the bottom and RTPRS type value versus predicted  
15 through all cracking frequency, there are two things  
16 that you can change that hope out on this plot. You  
17 can change the position of the vertical line -- the  
18 horizontal line, I'm sorry, as you pointed out, but  
19 you can also, as Bill was saying, he wanted to see  
20 some distributions.

21           I'm thinking, "Oh, God. I've got to go  
22 find some distributions." All the lines you'll see  
23 plotted today are 95th percentile not reflecting any  
24 policy decision, just based on normal scientific  
25 practice. What it does suggest is that there are

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1 distributions behind all of these lines. Of course,  
2 that means that 95 percent of the failures are below  
3 the line.

4 Where the screening criteria comes up is  
5 really based on a combined decision of where the  
6 horizontal line goes and what percentile you put in.  
7 As a materials person it would be my hope that we  
8 could make those two decisions and then do the  
9 screening based on best estimate values of the  
10 horizontal access variable.

11 You could keep the risk criteria where it  
12 is and pick a 99.999 percentile. I'm not suggesting  
13 that is a good thing to do, but achieve the same  
14 result as a very low risk criterion in a 25th  
15 percentile.

16 I think those are the decisions and if we  
17 think about them in that way, we can think about them  
18 in a rational scientific way as opposed to letting  
19 ourselves be led around by what the numbers actually  
20 are.

21 CHAIRMAN FORD: I guess this is a topic  
22 that will undoubtedly come up further than today. If  
23 you're talking about one sigma type of methodology,  
24 should you not be -- if you go for a 95 percentile --

25 MR. KIRK: Oh, yes. I see.

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1 CHAIRMAN FORD: -- the 95 percentile and  
2 given the urgency of this -- not the urgency of this  
3 problem, the potential severity of this problem,  
4 shouldn't you work into a six sigma or 99. whatever  
5 six sigma?

6 MR. KIRK: That's a very good point. By  
7 looking at it in this way, it enables us to think in  
8 that manner and make a decision consistent with the  
9 severity of the accident if it did, indeed, occur.  
10 Terry Dickson knows better what the tails look like on  
11 these distributions than anyone. Certainly the  
12 percentile that's picked should be appropriate to the  
13 severity of the accident.

14 MEMBER SHACK: Since we truncated .1 and  
15 99.9, we'll have a hard time probably going to it.

16 CHAIRMAN FORD: Sorry. We have talked  
17 enough at this point.

18 MR. KIRK: Yes.

19 MR. HACKETT: I guess a couple of comments  
20 I'll add just in closing of this sort of opening  
21 session here. This has been a really focusing event  
22 for the team. I've got to say the team has worked  
23 really hard on preparing for this presentation.

24 I think it was very good to have Professor  
25 Apostolakis point us in this direction because it

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1 pointed out some things both in a good and bad sense  
2 where we needed to spend some more attention. It has  
3 involved all three disciplines in the Office of  
4 Research and a lot of cooperation with the industry  
5 and with NRR.

6 That has come off remarkably well. It's  
7 fair to say it's not something that we're used to  
8 doing. We're getting better at it but I think it's  
9 about as good as it's been on this project.

10 Maybe just as a last anecdotal comment, a  
11 lot of credit to especially Mark Kirk for bringing  
12 this together including his facility with PowerPoint.  
13 You'll come to appreciate that he made all this  
14 possible today because the team was here fairly late  
15 last night getting things together.

16 MEMBER SHACK: You just need a printer  
17 that comes up with his skills.

18 MR. HACKETT: And you need to keep the  
19 files smaller. Also slides curtesy of Kinkos because  
20 the NRC reproduction facilities weren't able to  
21 accommodate our tight schedule here either. A lot of  
22 credit to the team and hopefully we can launch now  
23 into more detailed discussion.

24 I'll turn it over to Mark.

25 MR. KIRK: Okay. Thank you. Actually, I

1 only have a few slides here and then we go quickly to  
2 Alan. We are in the part of the agenda here, I think,  
3 this was previously item 4 on your agenda. Actually,  
4 items 4, 5, and 6 on your agenda. They've gotten  
5 moved up and we'll do the Oconee results after this.

6 Just to seal yourself, this is probably  
7 going to take us about three hours to walk through.  
8 As always, questions invited along the way so that we  
9 can get our voices back.

10 The purpose of this phase of the  
11 discussion is to work through the overall modeling and  
12 uncertainty process that we have undertaken in this  
13 project. In terms of what you're going to see here,  
14 the first two bullets are like one slide each and then  
15 the last bullet is approximately 30 slides per  
16 discipline so there is an uneven weighting here.

17 I would like to discuss the guidelines  
18 that we establish for doing uncertainty models in this  
19 project and talk about our intentions regarding the  
20 material screening criteria; discuss the interaction  
21 and integration of the three technical disciplines;  
22 and then, of course as everyone is aware, concept for  
23 model development on uncertainty treatment was  
24 established in 1999 by Nathan Siu.

25 You've been briefed on that already.

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1 Today what we're going to focus on is what actually  
2 happened. As Ed has already pointed out, you'll see  
3 that sometimes theory meets practice.

4 Other times practice falls a bit short of  
5 theory but the aim of this presentation is to present  
6 this with a good degree of candor so you get a good  
7 picture of what happened and, indeed, what did not  
8 happen.

9 The guiding principles that we started  
10 with were sort of those laid out by Nathan. The  
11 methodology that we've adopted in the PTS reevaluation  
12 project requires an explicit treatment of  
13 uncertainties across all of the technical disciplines.

14 As Ed pointed out, relative to where we  
15 are now in 10 CFR 5061, that is a bit of a departure  
16 where uncertainties tend to be -- it's like relatives  
17 you don't like. You tend to bury them and hide them  
18 in parameters. Well, they are all out here in the  
19 open now and we're going to talk about them.

20 We classify uncertainties as being either  
21 aleatory or epistemic. Those are my two new words for  
22 last year. Now that we have identified them and given  
23 them a name, we can put a number on them and then put  
24 them in the FAVOR code and Terry swims laps while the  
25 FAVOR code is running.

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1           The second point on this slide is that our  
2 intent in where we are going with this is to, of  
3 course, reset, or hope to reset, the material  
4 screening criteria for vessel embrittlement which is  
5 right now called RTPTS as expressed in 10 CFR 5061.

6           Our hope has been that in going through  
7 this we won't be requiring the licensees to make any  
8 new measurements. It will be able to use the advanced  
9 state of knowledge of computation of whatever is  
10 developed over the last two decades to be smarter  
11 about the screening criteria, but still express it in  
12 the same way relative to NDT, chemistry, and Charpy  
13 data. Everything is looking good with regards to that  
14 intent right now, I should say.

15           CHAIRMAN FORD: That last sentence, no new  
16 material measurements, when you're doing this project,  
17 you are obviously.

18           MR. KIRK: Certainly, yes. As associated  
19 with the project, the new measurements have been  
20 predominately focused in the flaw area. We have,  
21 indeed, collected together a lot of toughness data but  
22 that's not necessary new measurements. I should say  
23 no new surveillance measurements by the licensee.

24           MR. HACKETT: I guess including a couple  
25 of comments there, too, including things like the

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1 inspections. We've had those discussions. At least  
2 the idea going into the project was that it wasn't  
3 going to result in a new level of inspection  
4 technology that would be required on vessel wells.

5 CHAIRMAN FORD: The way it's written right  
6 now hits a raw spot with me in that you didn't do  
7 anymore experiments in this project and that's not  
8 what you meant.

9 MR. HACKETT: No, not at all.

10 MR. KIRK: Actually, we softened that  
11 statement from some that we had previous. Another  
12 example could be, for instance, the work of Ernie  
13 Eason and Bob Odette and others on the embrittlement  
14 correlation flagged up that phosphorous looks to be a  
15 contributor again as it was at the very beginning.

16 That then raises a question how does the  
17 industry address that. Is that a new measurement they  
18 need to make or are there default values or other ways  
19 you can address that.

20 And it looks like the answer is there will  
21 be -- there are alternative ways of addressing that.  
22 That is the kind of example. That did flag up out of  
23 the technical assessment and it will have to be dealt  
24 with.

25 MR. KIRK: Okay. Actually, we've used

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1 this graphic before and you'll probably get sick of it  
2 by the end of the day. This is the very highest level  
3 view of what's going on in this project. Like I said,  
4 we will be referring back to it just so you can see  
5 where you are.

6 We, of course, start with the PRA event  
7 sequence analysis. That gives us two things, both  
8 sequence definitions and sequence frequencies. The  
9 sequence definitions go into the thermal hydraulic  
10 analysis. We use the RELAP code to commute pressures,  
11 temperatures versus time from those. Those go into  
12 the PFM analysis which magically pops out a  
13 conditional probability of vessel failure. That is  
14 then combined in a deceptively simple matrix multiply  
15 with sequence frequencies to get the yearly frequency  
16 through all vessel cracking.

17 As we were dry running this yesterday my  
18 colleagues admonished me to point out that this is  
19 shown as a deceptively simple and linear process here  
20 and it's not either of those. Which is to say, we  
21 just don't pass through this once and call it a day.  
22 If we did, we would have met our schedule a lot  
23 better.

24 There's an awful lot of -- I shouldn't  
25 shall awful. Awful is a bad word. There's a lot of

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1 feedback that goes on at many points in this process  
2 as we get our results and it's just the normal  
3 engineering process of saying, "Well, that doesn't  
4 quite look right. What did we do there?" We feedback  
5 and we do it again.

6 As Ed pointed out on the status, and  
7 you've seen some of the results, and you'll see some  
8 more of those results today. We've got what we feel  
9 like is a good draft on Ocone. Having said that and  
10 going through that draft, we found certain things that  
11 they clearly need to be redone and will be redone but  
12 this is the overall process.

13 Now what we would like to do is to go  
14 through each of these three main elements, the three  
15 blue boxes, PRA, thermal hydraulics, and PFM and for  
16 each element present you with a presentation that in  
17 its total describes how we implemented our model  
18 development and uncertainty treatment procedures.

19 We are going to try to stick to this  
20 format as much as we possibly can to make it clearer,  
21 but in each of these three blue boxes we're going to  
22 start by talking about whatever constraints were  
23 imposed on the element or fundamental assumptions we  
24 have to make at the start. Those types of things  
25 would tend to constrain what we did.

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1           We will then break down those three  
2           deceiving simple blue boxes into many more boxes or  
3           lines or what have you. There is an awful lot hidden  
4           in there. It's kind of like Pandora's Box. We will  
5           then discuss the process used for model building, if  
6           indeed models were built, talk about uncertainty  
7           treatment, and we'll try to wrap up each presentation  
8           by focusing on significant changes since the 1980's  
9           evaluation providing a bit more meat to Ed's down  
10          green arrows and up red arrows that you saw earlier.

11                 With that, unless there are any questions  
12          --

13                 CHAIRMAN FORD: I've got a very, very  
14          general question.

15                 MR. KIRK: Sure.

16                 CHAIRMAN FORD: It's more for best  
17          practices for the future. Along with the thermal  
18          hydraulic code research is developing. This is an  
19          extremely multi-dimensional multi-disciplinary  
20          exercise. We are presuming it's going to work. We  
21          are positive.

22                 Do you have any lessons learned as to how  
23          you make such a thing work when you're talking to  
24          people on the west coast, the south presumably, in the  
25          east, the west?

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1 MR. HACKETT: We have enough challenges  
2 just within 2 White Flint or just at the NRC  
3 headquarters complex. I guess it's kind of a  
4 philosophical question.

5 CHAIRMAN FORD: It's more a management  
6 question which will increasingly become if not  
7 philosophical, real management.

8 MR. HACKETT: It's interesting. As I  
9 mentioned in the overview when we opened things up, we  
10 have been in the past, I think, guilty of being more  
11 compartmented here at the headquarters operation and  
12 with the contractors that we do our probabilistic  
13 fracture mechanics in our branch and David, Roy, and  
14 Alan, and others are doing PRA and thermal hydraulics.

15 There wasn't in the past, quite a while  
16 back now, as much cross-talk as there needed to be.  
17 This project has made that necessary. Mike Mayfield  
18 could give the best history of this you could possibly  
19 get.

20 Mike has made a number of stabs at trying  
21 to do this over the last decade. We have met with  
22 some significant challenges in the past because of  
23 failure in the interactions between the technical  
24 disciplines.

25 I think this is the first time it has

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1 really come together to work as well as it has, I  
2 think, frankly, it's out of necessity. We were just  
3 not able to make -- we can't run FAVOR without  
4 pressure temperature traces and event sequences and  
5 combine these into meaningful numbers for the rule  
6 without the kind of cooperation we've had.

7 I think it was those features plus an  
8 office director, Ashok Thadani, who got behind us in  
9 a very forceful way to have his three divisions taken  
10 on as a priority. It is one of the top priority  
11 projects within the Office of Research.

12 We've also had NRR supporting us all along  
13 the way. And then the industry, too. I think that  
14 was an element that was missing when we tried these  
15 things previously. We did not really work it  
16 cooperatively with the industry. We did this time  
17 from the very beginning and I think that's been  
18 another big factor. At least from my perspective  
19 those have been some major influences on the success  
20 we've had so far.

21 MR. MAYFIELD: This is Mike Mayfield. I  
22 think there are some things we have done differently  
23 from a management point of view. As Ed mentioned,  
24 this was taken on as a team activity involving inputs  
25 from all three of the divisions in the office. We had

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1 support from all three division directors.

2 The division directors meet basically bi-  
3 monthly briefing from the team on where they stand.  
4 The division directors meet separately on a regular  
5 basis and some of these top-tier programs that have  
6 high visibility are discussed.

7 We budget as a team activity rather than  
8 stovepiping the way we used to. The annual budget  
9 input is put together on an issue basis. There have  
10 been a number of changes like that that have  
11 contributed to making this go forward. I think they  
12 are lessons learned from some failures in the past  
13 that Ed mentioned and what is looking like a  
14 successful project right now.

15 We have adjusted. We've made some budget  
16 adjustments as we go along. By looking at it from an  
17 overall project standpoint rather than individual  
18 pieces I think we have been able to keep it moving.

19 MR. HACKETT: I think Roy had a comment.

20 MR. WOODS: This is Roy Woods. I'm  
21 involved with the PRA part of this. I heard Mike, and  
22 all that's true and very vital. But I also have to  
23 point out to you that the three of us at the lower  
24 level, PRA and myself, thermal hydraulics, Dave,  
25 Fracture Mechanics, partly, at least, Mark here, we

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1 meet sort of impromptu almost every morning now.

2 I wonder down to where their offices are  
3 and we've had some of the more meaningful and  
4 important exchanges of technical information or the  
5 way something is going or something that the other  
6 group needs to know about.

7 My point really here is in addition to  
8 what Mike was talking about where you made it a high  
9 level, director level, the workers also have to talk  
10 about the details of what's going on. I think that's  
11 been very important.

12 CHAIRMAN FORD: Thank you.

13 MR. KIRK: Coffee mess discussions have  
14 gotten us very far in this project.

15 MR. HACKETT: And it's Alan's turn.

16 MR. KIRK: With that, yes. We'll go to  
17 the detailed discussion of PRA models and uncertainty  
18 and I'll turn the presentation over at this point  
19 largely to Alan Kolaczowski of SAIC and Roy Woods of  
20 the staff.

21 MR. KOLACZKOWSKI: Alan Kolaczowski.  
22 First of all, thank you very much for the opportunity  
23 to, again, present the status to the committee  
24 members, etc. What I'm going to go over now is  
25 primarily address the key modeling aspects and the

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1 treatment of uncertainty in that first box that we see  
2 here on this diagram which is where we first define  
3 the sequence definitions that we're worried about.

4 Obviously a major product of that also is  
5 coming up with an estimate of the frequencies of those  
6 accident sequences that could represent a serious PTS  
7 challenge that is later combined with the conditional  
8 probabilities of vessel failure towards the tail end  
9 of the process to actually come up with estimates of  
10 the yearly frequency of thru-wall cracking.

11 This is, if you will, just another  
12 representation really of the same thing in the  
13 previous slide just shown perhaps in a little bit more  
14 detail. Unless you have specific questions, I'm not  
15 going to go through this in any detail but, again,  
16 this is meant to represent really what is going on  
17 throughout the entire project.

18 The PRA aspect of this, which is sort of  
19 the beginning part of the analysis through a primarily  
20 event tree modeling, we define what the potential PTS  
21 challenge accident scenarios could be and come up with  
22 the frequencies of those. Of course, those  
23 frequencies have uncertainties associated with them  
24 and we will be addressing that aspect of it later.

25 Those are binned and where sequences are

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1 likely to represent, if you will, very similar plant  
2 responses in terms of the way the plant will respond  
3 thermal hydraulically to those sequences. Those  
4 sequences are binned into what we call thermal  
5 hydraulic bins and then RELAP runs, etc., are run on  
6 those sequences to actually come up with the pressure  
7 temperature profiles for those sequences.

8 Now, again, while I'm presenting this in  
9 a very serial fashion. As has already been mentioned  
10 by Mark, this is quite an iterative process. You do  
11 some binning and you find out you've been too course  
12 or whatever and maybe, in fact, you've got to break  
13 those bins down into others and so you go back and you  
14 rebin those sequences and then more hydraulic runs are  
15 made so that we're not binning things quite so grossly  
16 where it looks as those something really does make a  
17 difference.

18 So, again, while we are presenting this in  
19 a very serial fashion, in fact, it's quite a iterative  
20 process and you go through this over and over and over  
21 again to keep refining the work to try to, if you  
22 will, remove many of the conservatisms that were  
23 certainly part of the original 1980's work.

24 MEMBER BONACA: Now here you include the  
25 operator actions in the binning process.

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1 MR. KOLACZKOWSKI: The operator actions,  
2 of course, are actually some of the events that are in  
3 the event scenario so the operator actions get defined  
4 as part of the event scenario. Hopefully that will  
5 become clearer as we move on to some of the modeling  
6 process. Surely by the time we get to the example  
7 sometime either very late today or tomorrow, hopefully  
8 we will demonstrate for you very clearly exactly how  
9 the operator actions --

10 MEMBER BONACA: The reason why I asked,  
11 you know, we're talking about the managing of this  
12 effort. I'm sure you had interactions with the plant  
13 or whatever.

14 MR. KOLACZKOWSKI: Yes, we did. I don't  
15 know of the Oconee staff are listening but I think  
16 they will verify that I probably asked them too many  
17 questions too many times. Again, they responded to  
18 all our needs and that was quite an interactive  
19 process going on with Oconee, for instance.

20 MEMBER BONACA: Good.

21 MR. KOLACZKOWSKI: As is going on with the  
22 other plants, Palisades, Beaver Valley, and so on.

23 MEMBER SHACK: Were there any physical  
24 changes in the plants that effected the event  
25 sequences that you looked at?

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1 MR. KOLACZKOWSKI: You mean from the '80s?

2 MEMBER SHACK: From the '80s, yeah.

3 MR. KOLACZKOWSKI: Well, I mean, to some  
4 extent certainly, yes. Oconee being a BNW plant has,  
5 of course, an integrated control system feature.  
6 Oconee has gone through an effort of updating that ICS  
7 system from the system the way it used to look back in  
8 the '80s time period. That is reflective ultimately  
9 on what the likelihood is of the integrated control  
10 system inducing faults that could cause PTS  
11 challenges, etc. We had to look at that. That is  
12 just an example. Probably if I thought about it a  
13 little harder I could think of some more.

14 Clearly one of the things that we had to  
15 do and did do in order to properly represent the  
16 potential PTS challenge scenarios for Oconee was get  
17 the latest information on what the plant looked like,  
18 how it's operated, what are the procedures they are  
19 using, what's the operator training, to what extent  
20 are they sensitive to PTS challenge, etc., etc. All  
21 of that needed to be, and was, done.

22 That's why we had to, in fact, interact  
23 with the licensee considerably to make sure that our  
24 model was indeed reflective of the way the plant is  
25 designed now, the way it's operated now, the training

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1 the operators go through, etc. There was a lot of  
2 work done in that area. That's just an example. If  
3 I thought about it, I could probably think of others.

4 So I'm going to be talking about, again,  
5 what's happening sort of in that first box in terms  
6 of, at least, some of the major modeling features and  
7 what we did in terms of handling, at least, the key  
8 uncertainties that we need to worry about, that  
9 portion of the analysis.

10 Okay. As the outline suggest, one of the  
11 first things we want to address is limitations or, if  
12 you will, constraints that we sort of impose on  
13 ourselves in terms of some limits that we put in terms  
14 of what we are going to analyze.

15 Also I want to point out a few keys things  
16 that were considered that are important to ultimately  
17 assessing what the PTS risk is from the PRA portion of  
18 the analysis.

19 Under limitations or, if you will,  
20 constraint side, I think we have to recognize that we  
21 are using an event tree PRA type of modeling structure  
22 to represent what those accident scenarios are. Along  
23 with that comes all the typical underlying PRA  
24 assumptions. Things are binary, although even there  
25 I know like a TBV, turbine bypass valve, is either

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1 going to stick open completely or it's going to  
2 reclose like it's supposed to.

3 Generally the model does not address it  
4 sticks open 30 percent or something like that. On the  
5 other hand, I should say that towards the end of this  
6 process, if we found out that something like that was  
7 very important and, in fact, it is in a few sequences.

8 The example that we'll get to at the end  
9 of this entire presentation will point that out, as a  
10 matter of fact, where we did have to go back and treat  
11 the fact, well, is the valve only 30 percent open or  
12 is it 80 percent open, etc., as part of the  
13 uncertainty.

14 Where it was important to do so, we did  
15 digress from the typical PRA binary look at the world.  
16 But in general it is a binary look at the world.  
17 Another example, the assumption that random events  
18 occurring follow some poison distribution process.

19 That's an underlying assumption that we've  
20 always used in PRA so you've just got to recognize  
21 that if you're going to model these sequences using a  
22 PRA event tree structure that there are some  
23 underlying assumptions that have just come along with  
24 the PRA process. Those are still there for the most  
25 part.

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1           The next thing I should point out is that  
2 there was a screening step performed before really the  
3 collective PRA information about the sequence as well  
4 as the T-H information about the sequence. Before  
5 that information was passed on to the fracture  
6 mechanics modeling there were some screening done.

7           For instance, the PFM folks did not  
8 analyze every sequence that comes out of the PRA  
9 model. There is something like 160,000 sequences, I  
10 think, in this model. We could not do 160,000 PFM  
11 runs or whatever. Even if you include the fact that  
12 we binned a lot of them, etc., there would still be  
13 many more than what PFM analyzed.

14           Largely that screening was done on what we  
15 think are very conservative either low frequency  
16 scenarios. In other words, the frequency was so low  
17 that even if you assumed the conditional probability  
18 of thru-wall crack frequency would be -- excuse me --  
19 that the conditional probability of vessel failure  
20 would be something approaching one and you just knew  
21 it was no way going to dominate the results. Those  
22 really, really low frequency scenarios were screened  
23 and weren't even analyzed in the PFM part of the  
24 analysis.

25           Similarly, on a T-H basis some of the

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1 accidents are some of the scenarios that are analyzed  
2 in the PRA model. Many of them, especially for taking  
3 credit for operator action, for instance, would lead  
4 to a pretty benign cooling event.

5 If it was pretty clear that either the  
6 rate of cooling that we were getting or, in fact, that  
7 the ultimate temperature that we would reach to were  
8 such that that rate was just so slow, say, well under  
9 the typical 100 degrees per hour cool down rate, or  
10 if, in fact, that the ultimate temperature that we  
11 would reach was something approaching 400 degrees in  
12 10,000 seconds into the scenario, clearly those kinds  
13 of cooling events are not going to represent  
14 significant challenges in terms of this phenomena  
15 occurring.

16 Where we saw that a scenario, even though  
17 it may have a high frequency, for instance, from the  
18 PRA aspect, was very benign from a cooling standpoint,  
19 then that scenario was screened and wasn't analyzed in  
20 the fracture mechanics portion of the model.

21 Having said that, I should point out that  
22 actually there wasn't a lot of screening done. I  
23 would say a lot of the scenarios passed through and  
24 were analyzed anyway just to make sure that they were  
25 not PTS challenges.

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1           The point is if it was pretty clear that  
2 the frequency was just so low, or the amount of  
3 cooling was just so benign that it was not going to be  
4 a dominate contributor to this challenge, the PFM  
5 folks never even saw that scenario so there was a  
6 certain amount of screening done.

7           As has already been pointed out, at this  
8 point in time external event types of scenarios,  
9 fires, floods, seismic, that could somehow cause an  
10 overcooling event and how would the operator respond  
11 to this event given that there is also a fire going on  
12 in the plant, for instance. That has not been  
13 analyzed yet. It will be.

14           We have an approach, a couple of  
15 approaches actually, outlined. Those are being  
16 reviewed and we should be planning to proceed on doing  
17 something in the external event area very shortly.  
18 Realize the results you're going to see now and the  
19 things I'm going to talk about don't address external  
20 events at all.

21           On the considerate side, I think a couple  
22 of key things that we need to keep in the back of our  
23 mind as we look at the results of Ocone and  
24 subsequent studies that are going on in terms of  
25 Beaver Valley and the other plants.

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1           We are looking at both full power and hot  
2 zero power, initial conditions. We are looking at  
3 different decay heat levels when this "overcooling  
4 event" occurs.

5           Obviously if you're at a hot zero powered  
6 condition and all of a sudden you have a severe  
7 overcooling event, the plant response is going to be  
8 somewhat different because it doesn't have that high  
9 decay heat to kind of slow the thermal response down  
10 in the plant. We are looking at both full power and  
11 hot zero power types of scenarios.

12           Secondly, the timing of the events.  
13 Again, a PRA event tree model in large part does not  
14 see time. It doesn't know when things happen. It  
15 just knows that they happen. Either a valve sticks  
16 open or it doesn't but it doesn't say when does that  
17 valve stick open.

18           For the large part, the model does not see  
19 time. However, having said that again, where time is  
20 important and where we did need to think about late  
21 occurrences of events or whatever, those have been  
22 included and, again, I think that will become clearer  
23 as we proceed through the presentation and  
24 particularly in the example when we get to it.

25           Finally, a point I want to make about

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1 operator actions is that typically in PRA we have  
2 always tended the model what we hope for the more  
3 important errors of omission. I think a serious  
4 attempt has been made to look at acts of commission.

5 In fact, there are a lot of -- I'm calling  
6 them acts on purpose because they are really not  
7 errors given the situation in most part. But there  
8 are conditions under which the operator will induce,  
9 if you will, a cooling to the primary system. Just to  
10 give an example, in a loss of heat sink type of  
11 accident where, let's say, we've tripped a plant and  
12 we've lost all feed to the steam generators.

13 One of the things the procedures and the  
14 training will direct the operators to do is to  
15 depressurize the secondary side of the plant to try to  
16 get feed into the steam generators by virtue of the  
17 condensate booster pumps.

18 That act of depressurization causes a  
19 cooling in the primary system because he's going to  
20 open up by-pass valves to depressurize the plant which  
21 is going to cause cooling but that's a proceduralized  
22 directed act of commission to, if you will, add  
23 cooling to the plant. Obviously the operator is going  
24 to try to do it in a controlled fashion and then not  
25 cause a serious overcooling event.

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1                   Nevertheless, those types of acts are  
2 included in the model and we actually did look for  
3 other types of acts of commission where it would be a  
4 mistake on the operator's part, if you will. Quite  
5 frankly, we didn't find too much in the way of  
6 contacts that would cause a high probability of that  
7 occurring.

8                   Nevertheless, there are procedurally  
9 directed acts which do add cooling to the event when  
10 it's necessary to do so to, for instance, avoid a core  
11 damage event and those acts are included in the model  
12 here.

13                   Finally, there are four functions of  
14 interest really that we are looking at and I'm going  
15 to point those out here in the next slide if there are  
16 no questions on this one.

17                   This is sort of a complex diagram and I  
18 certainly don't plan on going through each and every  
19 line of this unless there are questions from the  
20 committee. I think the main thing that I want you to  
21 walk away from in terms of looking at this diagram,  
22 this is a functional representation of the types of  
23 scenarios that are actually in this 160,000 sequence  
24 model that we have super simplified down to one page.  
25 As you can see, what we are really looking at is some

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1 sort of an initiating event that comes along either  
2 while the plant is operating at full power or as a hot  
3 zero power condition.

4 Then we're looking at the status of four  
5 functions that are listed there across the top. What  
6 is the status of the primary integrity. For instance,  
7 do we have a loss of cooling accident going on or is  
8 the primary basically still intact.

9 What is the status of secondary pressure.  
10 That's where you're covering things like do we have a  
11 turbine by-pass valve stuck open that is  
12 depressurizing the plant and causing a cooling of the  
13 primary system.

14 What is the status of secondary feed. Is  
15 that being properly controlled or are we indeed  
16 overfeeding the steam generators which also, again,  
17 could induce cooling in the primary system and,  
18 therefore, have an effect on the downcomer wall.

19 Then, finally, what is the status of the  
20 primary flow and pressure conditions. This is where  
21 you address such things as high pressure injection,  
22 potential repressurization events, are the reactor  
23 coolant pumps on or off because, again, that's going  
24 to have something to do with the amount of mixing  
25 that's going on in the primary versus the potential

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1 for stagnation conditions.

2 Those are the four functions of interest.  
3 Let me just say that the model addresses not only each  
4 one of those functions individually but also all the  
5 interactions between them, as well as the fact that  
6 you can have combinations of those occurring at once.  
7 Maybe you are overfeeding the steam generator and at  
8 the same time there's a stuck open TBV so two of the  
9 functions are, in fact, inducing cooling in the  
10 situation.

11 All of those interactions, the multiples  
12 of those interactions, etc., are all handled as part  
13 of this 180,000 or 160,000 sequences. Unless there  
14 are questions on that, that was really all I was  
15 planning to go through there.

16 This and the next slide serve to  
17 illustrate sort of the process that went on in  
18 building the model. Again, I don't plan on going  
19 through this in a lot of detail unless there are  
20 questions. There are a few things that I want to  
21 point out about the process.

22 As with any modeling process, the first  
23 thing you've got to do is go out and get a bunch of  
24 information on what it is you are going to model and  
25 how you're going to model it.

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1           You can see there on the left sort of a  
2 long list of things that were collected in order to  
3 make sure that the model was going to be an accurate  
4 representation of the Oconee plant. You can see the  
5 list there. I won't go through it but a couple of  
6 things I do want to point out, especially the last two  
7 bullets there.

8           We had the fortunate luxury to be able to  
9 visit the Oconee plant and actually spent, I think,  
10 like two or three days there the first time that we  
11 went. During that process Oconee staff and some of  
12 their regular crews were able to perform, I think in  
13 their case, three or four transient scenarios,  
14 different scenarios that represented overcooling  
15 situation.

16           We got to observe the interactions of the  
17 crew, how they operate, roughly how long did it take  
18 to get through various steps in the procedures, etc.  
19 That helped us an awful lot on the human reliability  
20 aspects of this portion of the analysis. I want to  
21 thank the Oconee staff for providing that simulator  
22 time to us and helping us through that aspect of the  
23 analysis.

24           Then lastly the interactions. Again, this  
25 went on continuously. I don't know if Steve Nader is

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1 listening but if he is, he'll tell you that we bugged  
2 him way more times than they were hoping. If we had  
3 questions about anything, "How does this ICS system  
4 work again?" etc., etc., "Where would the operator be  
5 in this step of the procedure at this point in time?"  
6 Whatever questions we had, we would e-mail those  
7 questions to them and the licensee was very prompt in  
8 providing responses to us. We would get on the  
9 telephone and we would discuss those responses. That  
10 was a continuous step throughout much of the analysis.

11 Again, a point I want to make was it isn't  
12 like we visited the plant on the first day, spent  
13 three days, and then never talked to them again. It  
14 was an ongoing effort through much of the analysis and  
15 almost up to the present time so there's a couple of  
16 things I want to point out.

17 From the information you collect, you  
18 begin to identify things that you need to make sure  
19 that the model includes and you can see a  
20 representative list of some of those things. I'm  
21 going to talk about some of the arrows in such a  
22 minute.

23 Then we started building the actual model.  
24 I just want to point out it's a large event tree,  
25 small fault tree type of modeling process. As I said,

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1 it's something like 150,000 or 160,000 sequences  
2 represented in the model.

3 At this step you put a model together.  
4 You include in it all the major equipment items that  
5 you need to model like the reactor coolant pump  
6 status, HPI injection, etc., etc. At this point I  
7 just want to point out this is where we did an initial  
8 cut of what the human error probabilities should be.

9 I should point out relevant to PTS  
10 challenges, especially for secondary events where we  
11 have a problem on the secondary, the operator plays a  
12 very key role in arresting that event. The human  
13 aspects of this are vitally important and need to be  
14 addressed. I think that's one of the major  
15 improvements that we made over some of the 1980's  
16 work.

17 Nevertheless, we have an initial model, an  
18 initial cut of accident sequences including human  
19 error probabilities and so on. There's a preliminary  
20 quantification of that.

21 At that point we went back to Ocone and  
22 while there was an internal review going on of the  
23 model, the preliminary results, the human error  
24 probabilities we put in, I should say at that point we  
25 already had not only mean estimates for those human

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1 error probabilities, but also had uncertainty bounds  
2 on those human error probabilities.

3 That was all looked at again by the  
4 licensee. We actually went back to Ocone and visited  
5 them, I think for a day, presented the preliminary  
6 results, left them with information on CDs and  
7 whatever, and then they provided comments back to us  
8 where they felt that we were either overly  
9 conservative or, even in some cases, I can remember  
10 one in particular, where the Duke staff pointed out  
11 that they thought we were a little too optimistic with  
12 our human error probability.

13 Nevertheless, it was give and take there  
14 where they commented on the preliminary results. So  
15 this analysis also took advantage of an intermediate  
16 step where the Ocone staff looked at our preliminary  
17 results, commented on that in terms of the PRA model  
18 structure, some of the data that we had, the human  
19 error probabilities, etc., provided comments back to  
20 us, as well as we, of course, were performing an  
21 internal review.

22 MEMBER SHACK: Where were your human error  
23 probabilities coming from? What models were you  
24 using?

25 MR. KOLACZKOWSKI: The human error

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1 probabilities, actually the way they were done on  
2 Oconee it turns out it's going to be slightly  
3 different from the way we may do it on some of the  
4 other plants. We had a number of, I guess for lack of  
5 a better phrase I'll call them, human reliability  
6 experts pull together among the NRC contractors.

7 Recognize that we had the procedures. We  
8 had observed these simulations, etc., and so forth.  
9 We had many discussions with the licensee. The first  
10 cut was that we went through essentially an expert  
11 elicitation process.

12 We looked at the various scenarios and the  
13 NRC contractors came up with an estimate of the mean  
14 probabilities as well as a cut at uncertainty bounds  
15 on the probabilities of human error failures and  
16 various conditions. As I pointed out, these covered  
17 again both errors of omission as well as what we  
18 thought were key acts of commission.

19 Then that was presented to the licensee  
20 when we went back to Duke. In fact, I sat down in an  
21 all-day meeting with a number of their operators and  
22 trainers, as well as some of their engineering staff,  
23 and we went through almost number by number what the  
24 human error probabilities were in the model and  
25 presented why we thought the means ought to be what

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1 they are, why we thought the uncertainty bounds ought  
2 to be what they are.

3 The uncertainty bounds did try to  
4 consider, if you will, the varying context of the  
5 scenario such as what if that key instrument were  
6 failed. How much higher would the human error  
7 probability get without that key instrument or  
8 whatever. Of course, now you've got to also factor in  
9 what is the likelihood of that key instrument failing.

10 Quite frankly this was done in, I'll call  
11 it, not subjective but I'll say a simplified manner.  
12 The point is the uncertainty bounds did try to account  
13 for variations on, if you will, the ideal state. That  
14 was all gone over with the Duke staff. Then they  
15 provided us some comments on the spot on some of those  
16 as well as then provided some written comments later.  
17 We incorporated those comments where we thought it was  
18 appropriate.

19 To that extent it certainly reflects not  
20 only the contract or expert's opinions on what those  
21 probabilities of failure should be, but also the  
22 licensee's feeling on what those probabilities of  
23 failure should be through the comment process.

24 Let me just mention on some of the other  
25 plants we are actually like in Palisades I'll just

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1 point out that we actually sat down with the licensee  
2 and came up with the human error probabilities  
3 together as a group through an expert elicitation  
4 process.

5 To that extent we have even done, I think,  
6 a little better job on Palisades as opposed to Oconee  
7 where the contractors did a first cut and then we had  
8 the licensees review and comment and then we changed  
9 accordingly where we thought appropriate.

10 In the case of Palisades we actually sat  
11 down together. Licensees and contractors were among  
12 the experts and we came up with what we thought the  
13 human error probabilities ought to be.

14 CHAIRMAN FORD: Alan, this whole question  
15 of human performance is not my area but you did  
16 mention that it was a large input to your overall  
17 event tree scenario. When you look at Ed's view graph  
18 7 and 6, are these curves in view graph 6 going to  
19 change much if Oconee is a good plant. They are good  
20 operators. Presumably there are some bad operators.  
21 Will the bad operators markedly move those curves?

22 MR. KOLACZKOWSKI: I don't think so. You  
23 have to recognize that you are asking a question where  
24 I'm trying to now predict what are all the other plant  
25 analyses going to look like.

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1 CHAIRMAN FORD: Right.

2 MR. KOLACZKOWSKI: I guess I'll just say  
3 this. I'll try to answer it this way and we'll see if  
4 that is satisfactory for you. I think certainly today  
5 in the year 2000 we are much more sensitive to  
6 worrying about PTS than perhaps we were back when  
7 these analyses were originally done which is  
8 representative more of late '70s, early '80s kind of  
9 event in terms of procedures, training, etc.

10 I think the industry at large has made  
11 vast improvements in terms of dealing with potential  
12 overcooling events and that is reflected in the way  
13 the procedures are written, whether it's a BNW plant  
14 or a Westinghouse plant or a CE plant. A lot of  
15 improvements have been made in the procedures and the  
16 training to be more sensitive to overcooling, to  
17 control overcooling events, etc.

18 Having said that, as a result, I have a  
19 feeling that a lot of the secondary kinds of scenarios  
20 that can cause overcooling, be they overfeeds to the  
21 steam generator, be they secondary depressurizations,  
22 etc., I think the procedures today and the training  
23 today in large part, no matter which plant we look at  
24 -- again this is a presumption on my part but you  
25 asked me the question and I'll try to answer as best

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1 I can -- I think are such that we are going to find  
2 that the operators are going to take actions fairly  
3 promptly to deal with that situation.

4 Therefore, almost because of through their  
5 acts we can make a lot of the secondary kinds of  
6 overcooling events go away to the point that the  
7 training and the procedures we are going to see  
8 throughout the 3 NSSS vendors a consistency in terms  
9 of that there is a concern about overcooling, that the  
10 operators are trained to address those, the procedures  
11 are written to address them promptly.

12 I would hope that we are going to find  
13 across all the plants that one day you will be able to  
14 give a considerable amount of operator credit for  
15 arresting those events before they become serious  
16 overcooling events.

17 That leaves the primary side. On the  
18 primary side, depending on the nature of the event,  
19 let's say, for instance, we take small loss of coolant  
20 accidents which are going to lead to overcooling  
21 situations and we need to inject obviously to deal  
22 with the loss of inventory, in that situation there's  
23 not much the operator can do, quite frankly.

24 I mean, the LOCAs happen, the cooling is  
25 going at some rate and they have to inject water into

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1 the plant. Obviously we do need to worry about  
2 throttling that water when we do meet those throttling  
3 criteria. That aside, at least during the initial  
4 1,000 seconds in the event, the plant is going to  
5 respond the way it's going to respond and there's not  
6 much that can be done.

7           There the operator does not, in fact, at  
8 least during the early phases of that accident, play  
9 all that significant a role. I guess I'm giving a  
10 long answer to your question but I think to the extent  
11 that we find that the procedures and the training are  
12 reasonably consistent and there is a sensitivity to  
13 PTS challenges, hopefully we will continue to show  
14 that the operator can arrest a lot of the secondary  
15 kinds of problems.

16           The primary, there are some that you just  
17 can't do much about, at least during the initial phase  
18 of the accident. However much of cooling we are going  
19 to get, that's how much we're going to get and there's  
20 really not much the operator can do about it.

21           The point is that remains consistent  
22 regardless of whether we are looking at Calvert Cliffs  
23 or Beaver Valley or Fort Calhoun or whoever. The  
24 point that that continues to exist, I think we'll see  
25 these general conclusions kind of holding. Do I

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1 expect vast changes in that curve that we saw in slide  
2 7? My hope is that we won't.

3 CHAIRMAN FORD: Presumably jumping forward  
4 to maybe the very last graph, when the licensee in the  
5 future uses this new procedure, not the regular tried  
6 1.153 or whatever the number was, he's going to have  
7 to measure his HEP for his plant. No?

8 MR. KOLACZKOWSKI: I don't believe so. I  
9 think we're going to try to by being conservative  
10 about where we ultimately set the risk criteria.  
11 Hopefully we can make an argument that we are covering  
12 all the various plant designs that are out there as  
13 well as all the variance that there might be operator  
14 actions recognizing, as you said, that there are some  
15 different levels in terms of the amount of perhaps  
16 attention to this as an event.

17 There are different training programs,  
18 etc. Nevertheless, I think they all have some degree  
19 of homogeneity to it in terms of addressing PTF  
20 challenge events. I think we will try to take credit  
21 for that. Maybe Mark can provide a better response.

22 MR. KIRK: No. I don't think so.

23 MR. KOLACZKOWSKI: Well, we certainly  
24 aren't going to ask all the plants to do a human  
25 reliability test.

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1 MR. KIRK: No. Maybe I would just like to  
2 say two words and then expound on them; screening  
3 criteria. We are trying to develop a screening  
4 criteria in the same sense that we've got one now and  
5 accepting the fact that right now it's widely regarded  
6 that the screening criteria is the limit and you just  
7 give up.

8 The fact is it is a screening criteria and  
9 you can do other things like Reg Guide 1.154. I am  
10 reminded of getting letters in the mail from my  
11 financial adviser with the big warning that says,  
12 "Past performance does not indicate future trends."

13 Right now the trends are pretty positive  
14 that if we continue to go the way of the Oconee plant,  
15 that we could be looking at raising the screening  
16 criteria by anywhere from 30 to 80 degrees, just to  
17 pick numbers out of the air.

18 Perhaps more importantly, that screen  
19 criteria might be based on mean values rather than  
20 adding margin terms that we do now. That provides a  
21 substantial relief relative to -- you cited Beaver  
22 Valley and Palisades that are right now sort of on the  
23 brink to provide that much of an increase in the  
24 materials screening criteria which, for all intents  
25 and purposes certainly for a 40-year license life,

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1 take PTS off the map.

2 I don't have the numbers stored in my  
3 brain for 60 years but probably there, too. Again,  
4 that is assuming things continue to go the way they  
5 are. If somebody crossed that line, then yeah, they  
6 would have to do a more detailed analysis and would  
7 have to quantify some of these things.

8 MR. HACKETT: That's what 1.154 would be  
9 about. As Mark said, that is not an option that has  
10 been a popular option. It may not be in the future.

11 One other thing I'll just make a comment  
12 on. Mark said you just want to be careful since this  
13 is a transcribed meeting, Beaver Valley and Palisades  
14 being on the brink. That would be at EOL, obviously  
15 not right now.

16 CHAIRMAN FORD: Yes, yes.

17 MR. HACKETT: And those are significantly  
18 in the future for both of those plants.

19 MEMBER SHACK: When you are comparing with  
20 the Oconee PRA, they would presumably screen a lot of  
21 these sequences out of their PRA since you don't have  
22 an embrittled vessel they don't lead to core damage.  
23 Do they include these and then screen them at some  
24 point? When do they get cut out of the PRA?

25 MR. KOLACZKOWSKI: In terms of the type of

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1 accidents that can happen or types of challenging  
2 scenarios that can happen?

3 MEMBER SHACK: Yes.

4 MR. KOLACZKOWSKI: As you see in the  
5 diagram right down here in the lower left it says, "No  
6 frequency screening," etc. We did not screen in the  
7 model at this point on the basis of --

8 MEMBER SHACK: I was thinking back to the  
9 Oconee PRA where presumably they don't consider PTS as  
10 a failure.

11 MR. KOLACZKOWSKI: Oh, in terms of their  
12 core damage scenarios.

13 MEMBER SHACK: They screen these scenarios  
14 out somewhere along the way and I was just wondering  
15 if they have them somewhere and you've gone back and  
16 compared with them or they have screened them out at  
17 such an early stage there's nothing to compare with.

18 MR. KOLACZKOWSKI: I wish in a way -- is  
19 anybody here from Oconee? Okay. I'm trying to  
20 remember. I don't think that their core damage model  
21 -- let me call it that -- probably has any significant  
22 PTS scenarios remaining in it. I hope I've said that  
23 correctly.

24 On the other hand, having said that, the  
25 PTS scenario work that was done in the '80s is

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1 probably in large part what they still represent as,  
2 if you will, their PTS risk. Okay? Now, that is  
3 essentially going to get updated, I'm sure, by this  
4 work.

5 Now, to what extent that this will get  
6 folded into their core damage model, I guess I really  
7 can't speak to that. You will have to ask Duke that  
8 question. Yeah, clearly their core damage model now  
9 certainly does not have a significant portion of it  
10 dedicated to worrying about PTS challenges.

11 This work, I'm sure, especially if they  
12 feel like -- I do think at this point they feel like  
13 it's a reasonable representation of their plant and  
14 their PTS risk. You would hope this will be reflected  
15 in their analyses in the future or whatever. Again,  
16 I can't speak to that.

17 MEMBER SHACK: You tried to make this sort  
18 of a best estimate, right?

19 MR. KOLACZKOWSKI: Best estimate with  
20 uncertainty.

21 MEMBER SHACK: More conservative than you  
22 typically are in a PRA. On an unlimited budget you  
23 would have done it even better.

24 MR. KOLACZKOWSKI: That is correct. But  
25 you're right. The purpose of this was to try to be

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1 best estimate. However, reflecting the uncertainties  
2 in all of the inputs that go in, and I'll be talking  
3 more about the uncertainties shortly. But, yes, it is  
4 meant to be a best estimate and not to be needlessly  
5 conservative where we don't have to be. That is  
6 correct.

7 MEMBER BONACA: Just a question I have.  
8 Regarding the primary system injection they were  
9 talking about some sequences where he doesn't have  
10 anything he can do.

11 On the other hand, I mean, if you have a  
12 large-break LOCA, clearly they will have a pressure  
13 challenge so you will have excessive cool down but you  
14 don't have a high-pressure challenge. If you have  
15 small-break LOCA, you would be hanging up there in  
16 pressure but you don't put in much water. Even feed  
17 and bleed sequences, it seems to me, you would have  
18 the same situation. This is pretty much self-  
19 controlling.

20 MR. KOLACZKOWSKI: Yeah, to some degree.

21 MEMBER BONACA: Only found some sequences  
22 which are, in fact, a challenge. I was trying to  
23 understand it.

24 MR. KOLACZKOWSKI: That is true. They are  
25 to some degree self-controlling. Again, I didn't mean

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1 to imply that if we have a loss of cooling action in  
2 the primary, well, that's it. We have a major PTS  
3 challenge and there is nothing the operator can do  
4 about it. If it came across that way, I apologize.

5 MEMBER BONACA: No, no, no. I was trying  
6 to understand, in fact, if the procedures would have  
7 to have some warning to the operator, for example, for  
8 bleed and feed in which you are intentionally open  
9 your PRVs and feed into the system. Even in their  
10 condition it's --

11 MR. KOLACZKOWSKI: It's only going to feed  
12 in so fast because obviously the pressure is at a  
13 certain pressure so the pump can only pump so much  
14 flow, etc. You are absolutely right. I mean, the  
15 smaller the LOCA, while the pressure may tend to stay  
16 higher, obviously the amount of cooling you get is  
17 going to be not as severe as if it was a much larger  
18 LOCA.

19 Then again, on that side, you also have  
20 the pressure staying relatively low so that is helping  
21 you to some degree. So you are right, there is some  
22 self-limiting features as to the way the physics  
23 works. What I was trying to imply is that in the  
24 first maybe 1,000 seconds of that event, really the  
25 operator is not influencing the event very much.

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1                   It's going to do what it's going to do and  
2 then at some point it begins to throttle back  
3 injections so that we don't get into a  
4 repressurization, let's say, scenario if the LOCA is  
5 small enough. Then the operator is also again  
6 influencing what the response is going to be  
7 thereafter. But in the first 1,000 seconds of the  
8 event, pretty much the plant is going to do what it's  
9 going to do.

10                   MEMBER SHACK: Let me rephrase Mario's  
11 question in perhaps a different way. Is there some  
12 small set of the 108,000 sequences that really  
13 dominate the PTS risk?

14                   MR. KOLACZKOWSKI: We believe so. Yes.

15                   MEMBER SHACK: Can we describe -- I mean,  
16 are we talking about LOCAs?

17                   MR. KOLACZKOWSKI: Maybe a dozen.

18                   MEMBER SHACK: A dozen?

19                   MR. KOLACZKOWSKI: A dozen of that order.

20                   MEMBER SHACK: They are slow-break LOCAs?

21                   MR. HACKETT: I guess we are preempting.  
22 Alan does get to this.

23                   MEMBER SHACK: Okay. Maybe we'll just  
24 wait then.

25                   MR. KOLACZKOWSKI: But the short answer is

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1 it's primarily LOCAs varying in sizes from very small  
2 to what I would typically characterize as maybe a  
3 medium break, not the double guillotine 34 or 30-inch  
4 line break.

5 MEMBER SHACK: LOCAs that could actually  
6 happen.

7 MR. KOLACZKOWSKI: Well, I don't know.  
8 That depends on your opinion of what could happen.

9 MR. KIRK: You've quantified the  
10 probability of that.

11 MR. KOLACZKOWSKI: We have quantified the  
12 probability of that. Small and medium LOCAs of  
13 varying types, relief valves sticking open, that kind  
14 of thing on the pressurizer.

15 CHAIRMAN FORD: Ed, Alan --

16 MR. KOLACZKOWSKI: We are going to  
17 describe later in more detail what the scenarios are  
18 that are dominated.

19 CHAIRMAN FORD: Okay. We are scheduled to  
20 have a break at 10:15. I don't want to destroy your  
21 crescendo here. I'll leave it up to you two to decide  
22 when we are going to have a break.

23 MR. KOLACZKOWSKI: I'll tell you what. If  
24 you'll let me just go through the next three slides  
25 and then I'll be ready to address the uncertainty,

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1 maybe that's a good place to do a break first. Is  
2 that okay?

3 CHAIRMAN FORD: Good.

4 MR. KOLACZKOWSKI: This is just a  
5 continuation of the process. I pointed out that we  
6 went through an interim step of sort of getting some  
7 preliminary results, going to Duke, getting some  
8 comments, etc., incorporating those comments where  
9 appropriate. Obviously there was a revision of the  
10 model, that step to incorporate those and requantify.

11 I should also point out that the binning  
12 that went on that I mentioned before, it wasn't like  
13 we took sequences, bin them once and then forever they  
14 were in those bins. As we learned more about what was  
15 dominating, about what was important to the plant  
16 response we may decide that we have to make the  
17 binning a little bit more refined than what we have  
18 currently done.

19 We would go back and redefine a new bin,  
20 rebin the accident sequences, do a thermal hydraulic  
21 run on that bin so we had a representation of what  
22 that bin represented, etc. There was an iterative  
23 process going on here as binning became more refined  
24 such that the bins really were a reflection of what  
25 the scenario really was as best as we could fit.

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1           We weren't doing these gross bins like  
2 back in the '80s work where they also had 180,000  
3 sequences and they put them into 10 bins. Whether it  
4 was a small steam line break or a large steam line  
5 break, thermal hydraulically looked like a large steam  
6 line break.

7           We were able to make those distinctions  
8 because we could run many more bins computer power  
9 being what it is today, etc., and so forth. I just  
10 want to point out that the binning kept getting  
11 refined, refined through this process.

12           Finally we get to a final quantification  
13 and binning step and out comes eventually for each T-H  
14 bin what the frequency is of the scenarios that fit  
15 into that particular T-H bin. That is really the  
16 primary product, a description of the scenario and  
17 what the frequency of that scenario is.

18           The only other thing I want to point out  
19 on both this and the previous slide is that you see a  
20 lot of arrows going to sequence definitions from  
21 various steps and then T-H input being provided back  
22 to the PRA process.

23           Again, that is just meant to be a  
24 representation. It isn't like we took the sequences  
25 and in one step provided them to the T-H folks and

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1 they ran a bunch of T-H analyses and then we went off  
2 and provided that stuff to PFM. This was highly  
3 interactive, kept occurring over multiple steps in the  
4 process to refine the interactions.

5 We talked about the fact that this project  
6 had to interact a lot between the PRA, or  
7 representation of this model, the T-H representation  
8 of these scenarios, and then the PFM folks.

9 This largely is just meant to show you the  
10 amount of interaction that was going on between the T-  
11 H folks and the PRA folks who had to talk to each  
12 other sometimes on a daily basis.

13 This is just meant to be a very quick  
14 summary of some of the major features of the model.  
15 On the left-hand side you see the initiating events  
16 that we included in the model. Let me just point out  
17 that they in large part are the same as what was in  
18 the '80s work but, in fact, we did include, I think,  
19 one or two things that perhaps the early work did not.

20 But for the large part there was not a  
21 significant difference here in terms of the initiating  
22 events that are modeled in this work as opposed to  
23 what was done in the early '80s work.

24 Again, you notice these were looked at  
25 both from a full-power and hot zero power condition.

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1 Then over on the right-hand side you just see a quick  
2 summary of, again, the four major functions that we  
3 are concerned with and the equipment that is  
4 represented in the PRA model.

5 What is the status of high pressure  
6 injection charging? What is the status of emergency  
7 feed? Is it overfeeding the steam generator? Is it  
8 underfeeding? Is it being properly controlled by the  
9 operator?, etc. You get a feel for the equipment that  
10 is manifested in the PRA model somewhere in terms of  
11 the status of that equipment.

12 Of course, another important part, as I  
13 pointed out, is the operator actions. This is, again,  
14 probably an over-simplification but, nevertheless,  
15 does represent the types of operator actions that are  
16 considered in the model some place.

17 I just want to point out again that if you  
18 look at the list you will see both examples of errors  
19 of omission but you will also see acts of commission  
20 such as under secondary pressure control operator  
21 creates an excess steam demand.

22 As I pointed out, in a loss of heat sink  
23 accident where we've lost all feed, they are going to  
24 purposely depressurize the secondary side of the plant  
25 to try to get condensate feed into the steam

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1 generator. Of course, they will try to do that in a  
2 controlled manner.

3           Nevertheless, the operator is inducing to  
4 some degree an excess steam demand event by procedure.  
5 That act is included as a potential mechanism for how  
6 we can get an overcooling situation in the plant.  
7 Again, this is a list of the types of operator actions  
8 that are considered in the model.

9           MEMBER BONACA: In the thermal hydraulic  
10 analysis did you assume, for example, complete mixing  
11 and just bulk temperatures, or did you have also an  
12 assessment of azimuthal in the vessel?

13           MR. KOLACZKOWSKI: I'll let Dave Bessette  
14 maybe answer that question.

15           MR. BESSETTE: Of course, the RELAP code  
16 doesn't only treat large volumes with a single fluid  
17 temperature so we had to address those questions  
18 differently. We did that for combination of the  
19 experimental program at Oregon State University in the  
20 apex facility.

21           Also looking back on the various mixing  
22 experiments we did back in the '80s in the aftermath  
23 of the first PTS study. In addition, we did some CFD  
24 analysis associated with the Oregon State work to  
25 compare where you do get three-dimensional fluid flow.

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1                   So the combination of the CFD analysis and  
2 experiments we were able to conclude that there are no  
3 substantial azimuthal or circumferential temperature  
4 variations in the downcomer adjacent to the core  
5 region.

6                   MEMBER BONACA: So you didn't apply any  
7 multiplier factor or anything of that kind? I mean,  
8 you didn't have to do that?

9                   MR. BESSETTE: That's right. We found a  
10 simple temperature boundary condition to pass on to  
11 the PFM people to sufficient and adequate.

12                   MEMBER BONACA: Okay.

13                   MR. HACKETT: As we had suggested, this is  
14 a good point to take a break.

15                   MR. DUDLEY: And during the break I would  
16 like to check the people who are on the bridge line so  
17 if they would stay there until we chat. Thank you.

18                   CHAIRMAN FORD: Okay. I hereby recess  
19 until 10:30.

20                   (Whereupon, at 10:14 a.m. off the record  
21 until 10:34 a.m.)

22                   CHAIRMAN FORD: Okay. I'd like to call us  
23 back into session. Since Graham Wallis will not be  
24 here until lunch time, I think Ed and I have decided  
25 to swap the EFM and the thermal hydraulic sessions to

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1 get a good reviewing.

2 MR. KIRK: It works for me. I'm not sure  
3 Dave would like it.

4 CHAIRMAN FORD: Okay.

5 MR. KOLACZKOWSKI: Shall I go ahead?

6 CHAIRMAN FORD: Yes.

7 MR. KOLACZKOWSKI: Okay. You've heard at  
8 least the major aspects of the modeling process and,  
9 if you will, at least some of the main features of  
10 what is included in the model in the way of the  
11 functions of the equipment that, therefore, was  
12 relevant equipment that we need to worry about, and at  
13 least a quick overview of the operator actions that we  
14 tried to consider.

15 I would like to now change focus a little  
16 bit and talk a little bit about the uncertainty  
17 treatment in this aspect of the entire analysis. This  
18 first slide here, No. 21, is meant again just to keep  
19 in mind in terms of what is the PRA portion of the  
20 analysis trying to produce. What is its product and  
21 ultimately working towards estimating a thru-wall  
22 crack frequency on the vessel.

23 I have a statement of that. Hopefully a  
24 somewhat succinct statement of what the PRA product is  
25 trying to produce and, therefore, what uncertainties

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1 we need to worry about.

2 Let me go ahead and -- I apologize. I'm  
3 going to go ahead and read the statement and try to  
4 focus on the key words. We are trying to come up with  
5 the frequencies of a wide range of representative  
6 plant responses to plant upsets. I'll call those  
7 plant responses the plant upset scenarios.

8 We are trying to get the frequencies of a  
9 wide range of scenarios that are each described by  
10 some set of thermal hydraulic curves in terms of  
11 pressures and temperatures and so on which occur as a  
12 result of mitigating equipment successes and failures  
13 as well as operator actions, that result in various  
14 degrees of overcooling of the internal reactor vessel  
15 downcomer wall.

16 Keep in mind here that we really have as  
17 an output unlike the typical core damage PRA type  
18 models where we sort of define a state of core damage  
19 and then we say, "Okay, does this scenario lead to  
20 core damage or not."

21 In this case, we have a much more complex  
22 situation in which you cannot define a single state  
23 that says this is overcooling or this is a PTS  
24 challenge and this is not. We actually have degrees  
25 of overcooling and, therefore, degrees of PTS

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1 challenges. In reality we don't have this binary  
2 output of either it is core damage or it's not.

3 What we really have is an output that says  
4 this represents some amount of overcooling which may  
5 or may not be a serious challenge from a PTS  
6 standpoint. This scenario represents yet a different  
7 degree of overcooling, maybe worse, that represents  
8 perhaps a greater challenge.

9 That is why you have to go through all  
10 this binning and separate those, etc. It isn't that  
11 all the scenarios are being binned to a single output  
12 that says core damage. These are degrees of PTS  
13 challenge that makes the process much more complex as  
14 a result.

15 Nevertheless, we are trying to come up  
16 with frequencies of scenarios that represent potential  
17 PTS challenges and they are various degrees of  
18 overcooling in the plant that could occur.

19 Now, in trying to come up with that  
20 product, of course, we build a model to do that. As  
21 a result, the model represents, to some degree of  
22 course, sources of uncertainty in that how accurate is  
23 the model really representative of the real world.  
24 We'll talk about that in just a moment.

25 Then even given the model which

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1 represents, if you will, these scenarios that are  
2 going to go on to the rest of the analysis and will be  
3 analyzed both thermal hydraulically and then where it  
4 is a serious challenge also model from the fraction  
5 mechanics point of view.

6 Even given the model then, of course, the  
7 other important product of this portion of the  
8 analysis is to come up with a frequency of scenarios  
9 each of which is an overcooling situation. Obviously  
10 there is uncertainty in what those frequencies are and  
11 we'll talk about that.

12 CHAIRMAN FORD: Alan, is it a given in all  
13 those scenarios that the pressure remains constant?

14 MR. KOLACZKOWSKI: No.

15 CHAIRMAN FORD: So is that not also the  
16 criterion?

17 MR. HACKETT: I was going to say you could  
18 probably have added to Alan's definition overcooling  
19 and potential overpressurization.

20 CHAIRMAN FORD: Maintenance of pressure.

21 MR. KOLACZKOWSKI: That is probably true.

22 CHAIRMAN FORD: Okay.

23 MR. KOLACZKOWSKI: I did not intend to  
24 mean that we did some sort of screening or didn't  
25 represent certain pressure situations or not. I did

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1 not mean to imply that.

2 Next slide. From the modeling  
3 perspective, again, what the PRA and the way PRA  
4 models the world, if you will, is that each scenario  
5 represents a collection, if you will, an interaction  
6 of events.

7 The plant is sitting there at some stable  
8 state, be it either at full power conditions or hot  
9 zero power conditions, and then along comes some sort  
10 of an upset, an initiating event, as we call it, which  
11 causes a transient and a subsequent response to be  
12 required in terms of the plant response.

13 The plant response depends on what the  
14 status is of various equipment, whether it be the  
15 status of emergency feed, whether it be overfeeding or  
16 being controlled, what is the status of the term by-  
17 pass valves, have they properly throttled or is one  
18 stuck open which causes an overcooling situation,  
19 etc., depending on the nature and the status of the  
20 various equipment that is relevant to a potential  
21 overcooling scenario or repressurization scenario.

22 Depending on the status of that equipment  
23 and the subsequent operator actions, you could view  
24 each scenario, if you will, as an initiating event,  
25 some status of equipment, and some status of operator

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1 actions which combine together either does lead to a  
2 overcooling type of scenario and it leads to a  
3 potential PTS challenge, or a very controlled non PTS  
4 kind of an event. That's the way the model  
5 essentially is representing the real world.

6 I want to point out, and I mentioned  
7 earlier, that the model is for the most part time  
8 independent. It doesn't necessarily know when these  
9 things are happening. It's just modeling the world in  
10 a way that says this initiating event has occurred.  
11 Either the valve has stuck open or has not, but we  
12 don't necessarily, at least in the first cut of the  
13 model, say anything about when the valve stick open.

14 Now, it does turn out that where that is  
15 important in describing the scenario and the potential  
16 amount of overcooling, etc., we do go back later and  
17 add timing into the situation. Again, I think the  
18 example later on will demonstrate that hopefully very  
19 well.

20 I do want to point out that there was a  
21 place where timing was introduced into the model right  
22 from the start, and that is when the operator action  
23 occurs. Recognize, as an example, we do have a  
24 secondary depressurization event going on, some sort of  
25 excess of steam demand.

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1           By procedure one of the things that the  
2 operator will be embarking on once they detect that  
3 situation is to isolate that faulted steam generator.  
4 How quickly the operator performs that in large part  
5 will dictate how much overcooling we get. The more  
6 delayed the actions, the more overcooling we will  
7 have. Whereas if he takes those actions very  
8 promptly, we'll hardly have any kind of overcooling  
9 event at all.

10           What we did do and, again, the example  
11 will demonstrate this, is that we did in the model  
12 from the start take this time continuum and break it  
13 into very discreet time points in which we said let's  
14 address and quantify sequences such that we are  
15 quantifying.

16           What's the likelihood that we have this  
17 initiating event, some status of equipment states, and  
18 the likelihood of the operator takes whatever the  
19 action is supposed to be within, let's say for the  
20 sake of argument, 10 minutes into the event.

21           If the operator does successfully perform  
22 those actions, maybe the event is for all practical  
23 purposes over. Maybe not even a very serious  
24 challenging event and would go into, if you will, a  
25 very benign overcooling bin.

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1                   On the other hand, in the model we also  
2 say what if he didn't take that action in 10 minutes?  
3 What's the likelihood that he would have taken it by  
4 20 minutes into the event and we reassess a  
5 probability for that likelihood.

6                   Now, obviously if the operator does not  
7 perform the action within 10 minutes time but does  
8 perform it within 20, he may have moderated the  
9 overcooling situation ultimately, but obviously as  
10 conditions got much worse before that arrest took  
11 place so that would perhaps go into a different T-H  
12 bin.

13                   We would actually perform a thermal  
14 hydraulic analysis of the same scenario with the  
15 operator taking the action in 10 minutes and then the  
16 same scenario with the operator action occurring in 20  
17 minutes and we put those in two different bins.

18                   MEMBER BONACA: Just for clarification,  
19 you're talking about time was of an element but if the  
20 cooling occurs at the rate which is less than the  
21 normal cool down rate, you will not consider it other  
22 ways.

23                   MR. KOLACZKOWSKI: That is true.  
24 Generally if a scenario was cooling down at less than  
25 100 degrees per hour, that was screened from --

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1 MEMBER BONACA: You just take it out.

2 MR. KOLACZKOWSKI: We still went ahead and  
3 kept it in the model and calculated a frequency for  
4 it. Ultimately none of that, primarily because of the  
5 thermal hydraulic response, as you say, would be a  
6 slow cooling situation was ever passed on to the  
7 fracture mechanics analyst who analyzed it.

8 MEMBER BONACA: You are using the word  
9 overcooling.

10 MR. KOLACZKOWSKI: That is correct.

11 MEMBER BONACA: To some degree, I mean,  
12 you still -- the main concern is temperature gradient  
13 across the wall or the vessel.

14 MR. KOLACZKOWSKI: That is correct.

15 MEMBER BONACA: That is a time dependent  
16 function. Even for those overcooling situations,  
17 which are benign, you are saying, at what point do you  
18 introduce the dependency so that you can eliminate  
19 some of those, or do you introduce the dependence at  
20 all?

21 MR. KOLACZKOWSKI: Well, in this -- I'm  
22 not sure I follow your question. In this portion of  
23 the analysis we did not, for instance, eliminate the  
24 sequence from being quantified.

25 MEMBER BONACA: Okay.

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1 MR. KOLACZKOWSKI: Even if we saw that it  
2 would be a fairly benign or slow cooling ramp, we  
3 didn't at that point say we're not even going to  
4 figure out what its frequency is. We kept it in the  
5 model and so many of those 180,000 sequences are, in  
6 fact, I'll call them relatively benign cooling  
7 scenarios but we went ahead and calculated their  
8 frequencies anyway so they are in the model.

9 MEMBER BONACA: So this benign definition  
10 you're using is more qualified in the sense that it is  
11 a slower cool down rate. There is still a cooling  
12 respect to the cool down rate but it's not such a  
13 challenge. I mean, you haven't attached any  
14 quantitative definition of what it means.

15 MR. KIRK: This is Mark Kirk. If I could  
16 just interject something that came up in our  
17 discussions yesterday that is perhaps relevant to  
18 point out here. Yeah, we made some -- well, I was  
19 going to say a priori assumptions but assumptions  
20 based on our previous understanding of PTS and we've  
21 already talked about them. Sequences where the mean  
22 temperature didn't fall below 400 sequences and it  
23 didn't cool at a rate in excess of 100 degrees  
24 fahrenheit per hour were not passed onto PFM.

25 Having said that, there were some

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1 sequences that were just over that line that were and  
2 we have quantitative information on them and those  
3 invariably came up with zero conditional probability  
4 failure. We haven't directly tested our screening but  
5 we no that those that just made it over the bar didn't  
6 matter anyway. I think that makes me feel good at  
7 least.

8 MR. KOLACZKOWSKI: Yes, it somewhat  
9 validates the screening that we did do.

10 Okay. So I talked about the fact that  
11 there is one very important aspect of timing that is  
12 introduced in the model from the start, and that is  
13 the timing of the operator actions. At some point we  
14 had to say if they do it by X minutes, we will make  
15 the assumption that the crew never does it. That  
16 would be the worst of conditions, if you will, that  
17 the operator does not arrest the situation at all.

18 Quite frankly, we use judgement as to when  
19 to pick those times depending on how fast the ramps  
20 were going down, when did we think it would matter.  
21 Again, a lot of that came from our prior knowledge of  
22 PTS conditions as to what were some reasonable times  
23 to pick that we would probably put the sequence into  
24 different bins and then pick those accordingly and  
25 came up with operator failure probabilities for the

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1 various times, had to account for dependencies, of  
2 course.

3 But at some point we said we are going to  
4 assume if they don't do it by this time that they will  
5 never do it and, therefore, that would be the worst of  
6 conditions and came up with a probability of the  
7 scenario actually going that far.

8 The other point I wanted to make -- the  
9 last two points is, again, for the most part modeling  
10 uncertainties were really not quantified per se. In  
11 other words, we built a model of the plant response in  
12 terms of the various statuses of plant equipment, what  
13 initiators could occur, whether operator actions  
14 occurred or not, etc., and we said that's our  
15 representation of the world.

16 It's a binary model for the most part as  
17 PRA normally is. However, having said that, what this  
18 third bullet is meant to imply here is that if we did  
19 have to worry about something additional that is not  
20 normally treated in a typical PRA model of the world  
21 such as when does the SRV reclose and, therefore, it  
22 could potentially repressurize the entire system.

23 We did go and address that as, if you  
24 will, a final step in the process. The model was  
25 initially built without worrying about the timing of

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1 the SRV reclosure. We just calculated what is the  
2 probability it will reclose. Then when we recognized  
3 that was a high enough frequency to worry about, we  
4 went back and addressed what would be the timing of  
5 that reclosure.

6 What is the probability it would reclose  
7 early versus what is the probability it will reclose  
8 late because that represents a very different thermal  
9 hydraulic response and we have to put those two events  
10 into two different bins.

11 We did make modeling changes to treat  
12 uncertainty of timing, for instance, and other factors  
13 but we only did it where it looked like it was going  
14 to be important, which leads to the final bullet.

15 Therefore, all other modeling  
16 uncertainties were not explicitly quantified. When we  
17 talk about the uncertainties ultimately of the  
18 frequencies that are passed on to the PFM portion of  
19 the analysis, much of the modeling uncertainties are  
20 not really quantified unless we deemed that it was  
21 important to do so and then we adjusted the model and  
22 came up with probabilities to try to address that  
23 aspect of the modeling uncertainty.

24 MEMBER BONACA: So you really leave it to  
25 the PFM analysis to make a decision whether or not a

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1 sequence should be eliminated? What I mean is that  
2 the same input that -- here you are using the  
3 frequency for the sequence and then the sequence is  
4 input to the thermal hydraulics that comes up with a  
5 certain profile of pressure and temperature versus  
6 time.

7 MR. KOLACZKOWSKI: Correct.

8 MEMBER BONACA: And that may say for this  
9 transient the probability is zero or very low so,  
10 therefore, you eliminate the sequence. That is really  
11 how you go through the logic process.

12 MR. KOLACZKOWSKI: That is true.

13 Okay. Now, the other aspect I mentioned  
14 was even given the model we often now calculate the  
15 sequence frequencies and there are uncertainties  
16 associated with that. I want to address a little bit  
17 about how we look at that from an uncertainty  
18 standpoint.

19 Again, just a reminder that each scenario  
20 is an interaction of essentially an initiating event  
21 along with the status of various equipment and along  
22 with the status of various operator actions which may  
23 or may not occur, or may occur at some time.

24 Therefore, you can think of each scenario  
25 -- oh, by the way, the model, therefore assumes that

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1 those events are, in fact, random events. We don't  
2 know what initiating event is going to happen, when  
3 it's going to happen, although we do try to calculate  
4 a rate of its occurrence on a per year basis, for  
5 instance.

6 Again, we model the various states of the  
7 mitigating equipment. But in terms of when that  
8 initiating event occurs, how the mitigating equipment  
9 is going to act whether it's going to fail that  
10 particular time or whether it's going to succeed, that  
11 is treated as a random event with some failure  
12 probability, some failure rate associated with the  
13 occurrence of that failure.

14 The same thing with the operator actions.  
15 Think of it as another component of the system at some  
16 failure rate and the operator may or may not perform  
17 the action quickly or in a delayed fashion or  
18 whatever. That is all treated as random events.

19 Therefore, the occurrence of each scenario  
20 is a random event. There are many ways to challenge  
21 the vessel from a PTS viewpoint. We talked about  
22 180,000 sequences from benign to various serious  
23 challenges. Which challenge is actually going to be  
24 the next one we don't know.

25 The occurrence of each scenario is really

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1 a random event and think of it as nothing more than  
2 the probability -- excuse me, than the multiplication  
3 of the frequency of the initiating event which is a  
4 random event times the probability of the equipment  
5 response times the probability of the operator actions  
6 all of which are random events so the scenario ends up  
7 being a random event.

8 I want to jump to the next bullet first.  
9 Therefore, the various scenarios and their frequencies  
10 are really characterizing, if you will, the aleatory  
11 uncertainties, the randomness of how we may get a PTS  
12 challenge.

13 You will see later that what Terry and the  
14 Oak Ridge folks do is that they sample from each one  
15 of those sequences to ultimately come up with this  
16 combination of sequence frequencies combined with the  
17 conditional vessel failure probability to come up with  
18 a distribution for what is the thru-wall crack  
19 frequency. They are sampling from each of those  
20 possible scenarios in terms of the way a PTS can  
21 challenge.

22 When they are doing that, what they are  
23 really doing is they are quantifying the aleatory  
24 aspects, the randomness of how PTS challenge can  
25 occur. Those scenario definitions and each one of

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1 those frequencies really represents the aleatory  
2 aspect of the uncertainty.

3 Now, along with the fact that each  
4 scenario is this multiplication of the frequency of  
5 initiating event and so on as you see in the equation  
6 there, obviously what we're trying to do is predict  
7 what we think is the true failure probability of the  
8 equipment, what is the true failure probability of the  
9 operator, etc.

10 Therefore, what is the uncertainty on that  
11 "failure rate" or that failure probability. There we  
12 are really addressing the epistemic uncertainties. We  
13 don't really have the knowledge to know what the true  
14 failure probability is for a turbine by-pass valve to  
15 stick open.

16 Nevertheless, we make an estimate as to  
17 what that is and we try to assess an uncertainty bound  
18 as to what that probability is. When we are doing  
19 that, we are addressing the epistemic uncertainties.

20 Those epistemic uncertainties, coming to  
21 the last bullet, are indeed propagated through the  
22 analysis using a Latin hypercube sampling approach.

23 Essentially when we go to calculate the  
24 frequency of a scenario, we are putting in  
25 distributions for each one of those inputs in that

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1 equation where that distribution represents the  
2 epistemic uncertainty on that probability or on that  
3 initiating event frequency.

4 Then we sample from those distributions to  
5 get a distribution out as to what the frequency of the  
6 scenario is. At that point what we're doing is  
7 propagating the epistemic uncertainties through.

8 Unless there are questions on this, I'll  
9 move on to the next slide.

10 Okay. That's a quick overview of how the  
11 uncertainty is being handled. Now, I do want to  
12 address just briefly what is different between this  
13 work and the previous 1980s work. What are sort of  
14 the dominate things that are different.

15 What you see, anything here in the red --  
16 and I apologize for those that have a black and white  
17 copy of this, but what you see in red are those things  
18 that tend to -- would tend in general to increase the  
19 PTS risk from what was done in the earlier work.

20 What you see in green are those things  
21 that we have changed from the earlier work that would  
22 tend to decrease the risk from the early assessment.  
23 You can see here, and I mentioned before that pretty  
24 much the initiating events and, for the most part, a  
25 lot of the scenarios that we have modeled were in

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1 large part covered by the earlier work.

2           However, we did do what is characterized  
3 here as a slight extension of some of the possible  
4 scenarios. In fact, you will find out that the  
5 example one we're going to go through, one of the more  
6 dominate scenarios, is a scenario that was not  
7 included in the original analysis.

8           There has been a slight expansion of the  
9 scenarios that we analyzed relative to the '80s work  
10 and also some of the treatment of the support systems  
11 like instrument air and component cooling and that  
12 kind of stuff.

13           Those in general tend to increase the  
14 risk. The more scenarios you add, the risk is going  
15 to go up. If you fail to analyze a particular type of  
16 scenario before and we're analyzing it now, that's  
17 going to generally add to the risk.

18           On the other hand, by using the latest  
19 equipment failure probabilities, initiating event  
20 frequencies, I know the staff is well aware of the  
21 fact that if we look at the number of plant trips that  
22 we're having these days on a per year basis versus  
23 what we were having back in the '70s, we used to have  
24 six A transients a year that could potentially lead to  
25 overcooling events.

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1           Now most plants are operating at half a  
2 trip per year kind of rate. Obviously that kind of  
3 information being reflected in the current analyses is  
4 tending to decrease the overall PTS risk.

5           The detail HRA. I pointed out the fact  
6 that in the early work for the most part there was  
7 either very simplified treatment of the human or, in  
8 fact, in many scenarios, little to no treatment at all  
9 or credit was given to operator actions. We are doing  
10 much more now to credit the operator actions where we  
11 think it is appropriate to do so.

12           I think we went through a very detail  
13 expert elicitation licensee involvement process to try  
14 to come up with best estimates and error bounds on  
15 those human failure probabilities for the scenarios.  
16 You can see some features of the HRA process here  
17 which I won't go through unless you have questions.

18           Again, the last sub-bullet there,  
19 consideration of acts of commission that could  
20 exacerbate cooling, again, those things would tend to  
21 increase the risk where you include that.

22           Very important point, much more binning  
23 than we ever did before. I think that is something  
24 that should not be overlooked. Never mind the values  
25 and the numbers that went in and so on and so forth.

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1           Just the fact that rather than having to  
2 put everything into 10 bins, we could put things into  
3 100 bins has removed a lot of the conservatism in the  
4 original analysis because we could do a much more  
5 finer scenario definition to bin process such that the  
6 bin really represents a few scenarios that are really  
7 quite representative of that bin and didn't put in,  
8 for instance, small main steam line breaks into a bin  
9 that has large steam line breaks and then treat it as  
10 large steam line break. We are able to avoid those  
11 kinds of issues.

12           Obviously the uncertainty analysis itself,  
13 just doing it probably in general does tend to  
14 increase the risk -- I've got to be a little careful  
15 here -- in that from a best estimate point of view  
16 when you do the uncertainty analysis you are  
17 accounting for those tails out there that do tend to  
18 bring the mean up than where they would be if you were  
19 just doing a best estimate point estimate analysis.

20           You do have to keep in mind that the  
21 original '80s work, however, was conservatively done  
22 so from that aspect, I guess you would make the  
23 argument the uncertainty analysis probably isn't  
24 increasing the risk.

25           If they had added too much conservatism

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1 into the original analysis. But I'm just saying from  
2 a best estimate point of view if you were just doing  
3 a point estimate analysis, you do have to keep in mind  
4 if you do a full-blown uncertainty analysis, you are  
5 going to get some tails out there which are going to  
6 tend to increase your best estimate of the mean a  
7 little bit than if you were just doing a point  
8 estimate mean kind of evaluation. I've got to be a  
9 little bit careful about how I characterize that last  
10 bullet.

11 Unless there are questions there, those  
12 are some of the major differences, I think, between  
13 the work that we've done on the PRA aspect of this  
14 versus what was done in the early work.

15 Is that my last slide or is there --

16 MR. KIRK: You have one more.

17 MR. KOLACZKOWSKI: This is just meant  
18 again to be a cartoon as to what the major products of  
19 the PRA process are that then goes into the rest of  
20 the analysis. There are really two things that are  
21 coming out, although one of them is really contributed  
22 by the T-H folks, and that is what is coming out of  
23 this whole process is a scenario that is being  
24 described by a set of thermal hydraulic curves.

25 Then there is a frequency associated with

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1 that bin or that scenario, if you will. That  
2 frequency is being described by distribution, by a  
3 histogram, which is representative of the epistemic  
4 uncertainty in the frequency of each one of those  
5 scenarios.

6 You see there we basically describe that  
7 distribution using 19 quintal levels. There was also  
8 a 95 percent confidence interval put on each quintal  
9 value. That information along with the T-H curves  
10 that represent that scenario is what was passed onto  
11 the fracture mechanics people for them to do their  
12 thing.

13 Last slide.

14 CHAIRMAN FORD: Sorry. I'm being a bit  
15 slow here.

16 MR. KOLACZKOWSKI: That's okay.

17 CHAIRMAN FORD: You see the density, that  
18 --

19 MR. KOLACZKOWSKI: That's a probability of  
20 distribution function of the -- that's our belief on  
21 what the true frequency of the scenario is.

22 CHAIRMAN FORD: So that distribution code  
23 is for a specific --

24 MR. KOLACZKOWSKI: T-H bin.

25 CHAIRMAN FORD: Okay.

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1 MR. KOLACZKOWSKI: T-H bin. Remember, it  
2 may have some multiple scenarios in them.  
3 Nevertheless, we think that they are all so similar  
4 that they can be represented by one set of T-H curves.  
5 Then essentially what you have to do, if you will, is  
6 add up the frequencies of all the sequences that are  
7 in that bin to get the frequency of that bin.

8 The frequency of that bin is ultimately  
9 represented by a distribution which we then broke into  
10 19 quantiles, etc., for descriptive purposes so that  
11 the fracture mechanics people could then go and sample  
12 from this distribution at the same time that they're  
13 sampling from the output of the PFM code to put  
14 together to get a thru-wall crack frequency in its  
15 distribution. I don't know if I cleared that up or  
16 not.

17 That is the uncertainty on what the true  
18 frequency of the bin is. You can describe that  
19 histogram by a mean 95 percentile, a 5, etc., so  
20 forth, and that's our description of the frequency of  
21 that.

22 CHAIRMAN FORD: Okay.

23 MR. KOLACZKOWSKI: I guess a couple of  
24 things I would like the community to walk away from  
25 the PRA aspect of this in terms of the modeling we did

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1 and the uncertainty treatment, I guess these are the  
2 major points.

3 We feel that we have modeled all the  
4 relevant initiators functions and equipment of concern  
5 that through the status of those could represent some  
6 sort of a potential PTS challenge. I keep saying  
7 this, I know, but operator actions plays a very key  
8 role in the arresting of many overcooling events.

9 To model the situation without operator  
10 action would obviously not do any justice at all and  
11 we would be back to the '80s work that gave very  
12 little credit to operator actions. I think we have  
13 tried to reflect that credit appropriately based on  
14 current day standards of procedures, training, and so  
15 on and so forth.

16 CHAIRMAN FORD: Just to make sure I  
17 understand, if you go back to VG23, I can understand  
18 what you have done in VG23.

19 MR. KOLACZKOWSKI: Okay.

20 CHAIRMAN FORD: I can understand the  
21 epistemic actions. I can understand the physical  
22 reality of what is happening there. The aleatory  
23 uncertainties don't mention that at all. How much is  
24 that going to affect your conclusions? I'm going to  
25 assume these are things that are completely random so

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1 how do you take that into account? Was it just --

2 MR. KOLACZKOWSKI: If I can go back to the  
3 overall diagram which would be like No. 7 and 13.  
4 When the [CPF] \* [fr] takes place, remember we are  
5 providing to that circle sequences and their  
6 frequencies.

7 CHAIRMAN FORD: Right.

8 MR. KOLACZKOWSKI: Each frequency has a  
9 distribution which is representative mostly of the  
10 epistemic uncertainty and what the true frequency is.  
11 Although, quite frankly there is some aleatory  
12 probably buried in that that is not separated but is  
13 largely represented in the epistemic uncertainties.  
14 Each sequence, and there's a lot of sequences, we  
15 don't know which sequence is going to happen that will  
16 represent a PTS challenge.

17 A collective set of sequences is  
18 representative of the randomness of how the next pTS  
19 challenge is going to occur. The PFM folks when they  
20 do this combination in the circle, they are picking a  
21 frequency value from every one of the sequences that  
22 could represent a PTS challenge when they do this  
23 combination of [CPF] \* [fr].

24 That is the place where the aleatory  
25 aspect of this; that is, the randomness of how the

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1 sequence is going to proceed gets factored into an  
2 estimate of the yearly frequency of thru-wall crack.  
3 Does that answer your question?

4 So that's where the aleatory is really --  
5 the aleatory really doesn't get treated until  
6 essentially the last step in the process but we are  
7 propagating the epistemic all the way through all the  
8 time. Does that help?

9 CHAIRMAN FORD: Yeah.

10 MR. KOLACZKOWSKI: I think I was on that  
11 last slide if there are no other questions. Again, I  
12 talked about we think the model is a pretty good  
13 representation. Again, modeling uncertainties for the  
14 large part, though, are not quantified except for  
15 where it's important.

16 We did at the end of the process have to  
17 go in and adjust the model to treat those, but the  
18 frequency uncertainty, the epistemic uncertainties are  
19 propagated all the way through. We determine or put  
20 a distribution on each one of the inputs, get a  
21 distribution on the output, propagate that all the way  
22 through to get a distribution on the frequency output,  
23 thus described ultimately as a histogram.

24 That is sort of a summary, if you will, of  
25 how the uncertainty is treated. The aleatory

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1 ultimately gets captured in that very last step. I  
2 think that hopefully will also become clearer as we  
3 get to that portion of the presentation. Does that  
4 help? I think that ends my --

5 MR. KIRK: That's your last slide.

6 MR. HACKETT: Any other questions for  
7 Alan?

8 CHAIRMAN FORD: When we go through Oconee  
9 we'll go through this again step by step.

10 MR. HACKETT: Right. Exactly.

11 MR. KOLACZKOWSKI: This is sort of an  
12 overview of the generalization. As we get through the  
13 Oconee and the example, hopefully some of this will  
14 even crystalize some more.

15 MR. HACKETT: As Peter mentioned earlier,  
16 we are going to look at another departure from our  
17 plan here. To accommodate Dr. Wallis' arrival we are  
18 going to now go into the probabalistic fracture  
19 mechanic aspects of the program in more detail. Mark  
20 and I talked and hopefully we can try to get at least  
21 most of that in before the lunch break. That will be  
22 our goal anyway.

23 MR. KIRK: It depends on how many  
24 questions Dr. Shack has.

25 If you go to view graph 60 in your

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1 handout, that is the beginning of the PFM part of the  
2 talk. So again, you see the most frequently used  
3 slide in the pack. We are now going to focus on  
4 expanding the probabalistic fracture mechanics  
5 process.

6 As I indicated, behind each of these blue  
7 boxes is sometimes a frightening level of complexity.  
8 Now what I am showing you is what is inside the PFM  
9 box. This is something like those Russian dolls. You  
10 keep taking them apart and you get more and more and  
11 more. You can either lose yourself or make a career  
12 in it, however you want to think about it.

13 This slide illustrates the first doll  
14 inside the box marked PFM. It's got both a material  
15 resistance side which is shown down at the bottom of  
16 the slide, and applied driving force side which is  
17 shown off to the left. We just worked through some of  
18 the steps in this. I'll be discussing the irradiation  
19 shift model, index temperature model, and fracture  
20 mechanics model in more detail.

21 We start off with data concerning  
22 chemistry, fluence, and, of course, temperature  
23 estimates from thermal hydraulics. That feeds into  
24 our radiation shift model. From that we estimate what  
25 the affect of irradiation at a particular temperature

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1 for a given length of time is on a material having a  
2 particular chemistry.

3 That tells us how much irradiation damaged  
4 our material. We add that to an un-irradiated index  
5 temperature which tells us where the toughness data  
6 was before. Irradiation started and that gives us an  
7 irradiated index temperature which we combine with a  
8 reference fracture toughness curve to get our fracture  
9 toughness resistance. Now we know in very general  
10 terms what the material can take.

11 To define the degree of challenge, we go  
12 over to the stress intensity factor model which  
13 combines thermal hydraulic inputs, design variables,  
14 physical properties like modulus, Poisson's Ratio,  
15 things like that.

16 And, of course, flaw data to get the  
17 applied stress intensity factor. A comparison of  
18 those two which is done in the code -- we'll show you  
19 the mathematics of that probably tomorrow -- allows us  
20 to estimate our probability of crack initiation and  
21 probability of thru-wall cracking.

22 Going through this process, we focused our  
23 model development and uncertainty efforts in the areas  
24 that I've highlighted now, for those of you looking on  
25 the screen, in yellow and in orange. It is relevant

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1 to point out here, because I don't have another  
2 opportunity to point it out, that certain things in  
3 this model have been taken as deterministic.

4 For example, design variables physical  
5 properties. This is not to say that the elastic  
6 modulus of the material is not variable. It is to say  
7 that when compared with other variabilities like  
8 fracture toughness and embrittlement, it's about as  
9 constant as the elevation in Champagne, Illinois, if  
10 you've ever been there.

11 Design variables like the vessel diameter  
12 are also treated as deterministic so we have made some  
13 judgements at the beginning of this model and decided  
14 to treat some things deterministically.

15 What I would like to do there are now two  
16 parts to this presentation. There's a discussion of  
17 the model development and uncertainty in the fracture  
18 toughness and embrittlement model that is highlighted  
19 in yellow. I'll go through that first. Then I'll  
20 discuss the uncertainty treatment in the flaw data  
21 which is highlighted in orange.

22 Just to benchmark ourselves for the  
23 fracture toughness and embrittlement models in terms  
24 of where we are and what we need to do, we start off  
25 with our existing toughness model, our existing

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1 embrittlement model, what we use today in 10 CFR 50.61  
2 to estimate the material state of the plant.

3 In all of this nontoughness data meaning  
4 data from Charpy specimens, NDT specimens is assumed  
5 to represent toughness data. When we get into  
6 uncertainty space, that presents us with some very  
7 interesting challenges. That assumption has led to  
8 uncertainties being treated implicitly and uncertainty  
9 types between aleatory and epistemic being mixed into  
10 a spaghetti bowl.

11 We needed to take that all apart in order  
12 to get this into a PRA framework because of the  
13 constraint that we stated at the beginning, or the  
14 intended constraint that we would like to come out of  
15 this with a revised PTS screening criteria that still  
16 relies on NDT and Charpy data. That was the hope. We  
17 believe we have achieved that but in order to deal  
18 with uncertainties, we need to take this apart yet  
19 further.

20 This slide discusses the constraints and  
21 fundamental assumptions that we have gone into, the  
22 fracture toughness model with one, which I stated  
23 before, is that we would like to come out of this  
24 still allowing the licensees to assess the state of  
25 their plant based on the nontoughness data that they

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1 now have.

2 We need to somehow express that  
3 nontoughness based model in the PRA context. Also we  
4 retained the linear elastic fracture mechanics basis  
5 of FAVOR. It would, of course, be possible to  
6 construct a version of FAVOR based on elastic plastic  
7 fracture mechanics. However, the nature of the PTS  
8 challenge rather says that a linear elastic model is  
9 appropriate so we've stuck with that.

10 Looking now at the process we've used in  
11 the toughness embrittlement models for building the  
12 models and characterizing uncertainty, I would like to  
13 just mention at this point, or I should say  
14 acknowledge the significant impact that the industry  
15 provided here through the EPRI MRP and their funding  
16 of their contractor, Marjory Detician, who was largely  
17 responsible for developing this whole process that  
18 enabled us to do a very good job of characterizing the  
19 uncertainties in a way consistent with PRA. Without  
20 that help from EPRI and Dr. Detician this would look  
21 much different.

22 So what we started with were two things.  
23 One was what we've been calling a root cause diagram  
24 which is really nothing more than just a graphical  
25 description of a mathematical process. The benefit

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1 here is it allows us to depict very clearly what our  
2 current process is.

3 For those of us that thought we understood  
4 the 10 CFR 50.61 process and said, "Oh, that's easy,"  
5 and then a month later said, "Boy, that was  
6 educational," it really allowed us to identify very  
7 clearly where the uncertainties were, or are I should  
8 say, where the judgements are.

9 If you can't identify them, you can't  
10 quantify them. That was our starting point. That  
11 told us where we needed to work. But we've also  
12 acknowledged at the start that because we are trying  
13 to stick with nontoughness based data to predict  
14 toughness data, we've got an estimate.

15 We've got a model and to assess  
16 uncertainty relative to that we need something else.  
17 We need something to compare to. What we focused on  
18 developing is what we referred to as physically  
19 motivated best estimate models.

20 If you only had data and you've got  
21 nothing else, then you've got no way to tell if your  
22 data is right or wrong. What we tried to do was to  
23 use our physical understanding of deformation of  
24 fracture to tell us how the data should behave and  
25 then calibrate those models based on available data.

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1           This also allowed us considerable insight  
2 into classifying uncertainty type as being either  
3 aleatory or epistemic. It really made quite clear  
4 those uncertainties that were just inherent properties  
5 of the material. No matter how much funding you had  
6 and how well you did your experiments, you would never  
7 get any better and those situations where the reverse  
8 was true.

9           When we combined these two things, the  
10 identification of uncertainties, our ability to  
11 classify them relative to a physical model and,  
12 indeed, our ability to quantify them relative to that  
13 model, that provided us with a means to account for  
14 uncertainty.

15           Down there in the red print on the screen  
16 you see sort of our mantra, "Fracture toughness data  
17 is truth. Fracture toughness data is truth." We kept  
18 getting back to that, that we certainly use the  
19 physical understanding to get insight into how the  
20 data should behave and that in many ways told us how  
21 we should be looking at the data but we kept  
22 referencing back to the idea that we are trying to  
23 predict  $K_{Ic}$  data or  $K_{Ia}$  data.

24           This all enabled us putting all this  
25 together to recommend a FAVOR procedure for both a

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1 model and an uncertainty treatment for all of these  
2 key parameters in the toughness equation, the  $RT_{NDT}$   
3 index temperature, the  $T_{30}$  shift, the RT arrest shift  
4 which gives us the distance between the initiation and  
5 the arrest curves and, of course,  $K_{Ic}$  and  $K_{Ia}$   
6 themselves.

7 What I'm going to do now, and if my memory  
8 serves me, we briefed the committee in detail about  
9 this before, is to just go through and hit the high  
10 points on each of these models. We have some backup  
11 slides that we can refer to if necessary. Certainly  
12 there is the draft NUREG that, I believe, was passed  
13 on to you.

14 There are three sequences of a few view  
15 graphs here that I'm going to step through. The first  
16 step along the way is the model of initiation fracture  
17 toughness. As the schematic on your screen shows,  
18 there are two parameters in this initiation model.

19 There's, of course, the toughness value  
20  $K_{Ic}$ , and then there's the index temperature  $RT_{NDT}$ . We  
21 need to have a model and quantify uncertainty in each  
22 of these. As I pointed out, to do that we need some  
23 independent arbiter of truth because we recognize that  
24  $RT_{NDT}$  is most certainly not truth.

25 So this slide depicts the end result of

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1 our best estimate model. Our understanding of the  
2 physics of deformation and fracture suggest that we  
3 expect, and indeed observe, a common temperature  
4 dependence in the variation of toughness with  
5 temperature that is common to all ferritic steels.

6 That temperature dependence depends only  
7 on the lattice structure and so we don't expect it to  
8 change with chemistry. We don't expect it to change  
9 with the radiation in the range of exposures that we  
10 get in reactor vessels.

11 CHAIRMAN FORD: Sorry. Did you say you  
12 wouldn't expect it to change with chemistry?

13 MR. KIRK: No, not unless the chemistry  
14 makes the steel not ferritic. As long as -- I'm  
15 sorry. As long as the lattice structure is body  
16 centered cubic.

17 CHAIRMAN FORD: There's a master curve of  
18  $K_{Ic}$  versus temperature for all --

19 MR. KIRK: For all ferritic materials  
20 without question. If you change it from being  
21 ferritic, it won't follow that master curve.

22 MR. HACKETT: I guess we don't want to go  
23 too far with this. Nothing, I guess, in science is  
24 without question.

25 CHAIRMAN FORD: No, no.

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1 MR. HACKETT: I think what Mark is going  
2 to go through is a lot of empirical data backing up  
3 those statements and a lot of analyses.

4 MEMBER SHACK: It does shift with  
5 transition temperature.

6 MR. KIRK: Yes. The effects of  
7 irradiation, and I get to that here, when you look at  
8 what irradiation does to the material it, of course,  
9 hardens the material which leads to a shift in the  
10 fracture toughness.

11 MEMBER SHACK: But even without  
12 irradiation you have a shift.

13 MR. KIRK: You have that index  
14 temperature.

15 MEMBER SHACK: So the master curve is  
16 indexed to a temperature.

17 MR. KIRK: That's right.

18 MEMBER SHACK: So all ferritic steels are  
19 not the same.

20 MR. KIRK: No. Absolutely not, but once  
21 indexed to a temperature, they all follow a common  
22 variation of toughness with temperature.

23 MEMBER SHACK: Yes. That's correct.

24 MR. HACKETT: And maybe to pursue it  
25 further, because I can Peter still musing over this,

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1 and it's been something that has been worked on for a  
2 long time. I think Mark answered it correctly. The  
3 chemical composition influence would be through its  
4 impact on crystal structure.

5 Obviously there are influences of the  
6 chemical composition on the end state crystal  
7 structure, but for most ferritic steels under these  
8 conditions, that variability is not there. It could  
9 be in other circumstances but not in the particular  
10 problem --

11 MR. KIRK: Not in these conditions. So  
12 what we see is certainly for the range of conditions  
13 that we're interested in here, the steels, the  
14 exposure conditions, the ranges of chemical release,  
15 our physical understanding suggest that we should  
16 expect to see, as we said, once indexed a common  
17 temperature dependence and, indeed, a common scatter  
18 to all ferritic materials of interest.

19 We find that the effects of irradiation,  
20 since they don't affect the crystal structure, and  
21 since they don't affect the micro-defects that are  
22 leading to the scatter in the  $K_{Ic}$  or  $K_{Ia}$  data, we  
23 effect irradiation to simply produce a shift in that  
24 transition temperature as is illustrated by the two  
25 graphs which have probably been shrunk too small.

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1           These physical expectations are backed up  
2 by, indeed, mountains of data. It's been said that  
3 the master curve hasn't yet met a ferritic steel that  
4 it doesn't like and I personally haven't found one.

5           I should also note that a couple of years  
6 ago I made it a quest to find one believing, as any  
7 good experimentalist did, that life just can't be that  
8 simple. I haven't found one yet. We've adopted as our  
9 best estimate to which we will compare are  $RT_{NDT}$ , the  
10 master curve method, with the  $T_0$ .

11           I'm sorry, Peter. Go ahead.

12           CHAIRMAN FORD: I must admit I'm still  
13 pondering over this master curve business and  
14 invariable. If you go back to VG 64, you've got on  
15 the left-hand side two examples of two steels, one  
16 from Midland and one from HSST program where they are  
17 markedly different from this master curve.

18           MR. KIRK: Well, actually, that's the  $K_{Ic}$   
19 curve, but go on. That's the  $K_{Ic}$ .

20           CHAIRMAN FORD: My point is if you just  
21 look at it as a reference curve, those gold lines you  
22 see there, the same curve.

23           MR. KIRK: Yes.

24           CHAIRMAN FORD: Big difference. Two sets  
25 of steel. Different T values which is fine. You

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1 would expect the difference in the half T and the 3 or  
2 4 T. Big difference.

3 MR. KIRK: In fact --

4 CHAIRMAN FORD: What physically is the  
5 reason for that?

6 MR. KIRK: I think -- maybe I'm not  
7 understanding what you're saying but, in fact, if you  
8 pass the master curve through each of those data sets,  
9 which would mean you would have -- if you assume that  
10 was the master curve, which it isn't, but if you  
11 assume that it was and you indexed it to  $T_0$  and you  
12 then did a statistical test to see how many were above  
13 the line and how many were below the line, and your  
14 statistical expectation would be 50 percent above and  
15 50 percent below, you would find no reason to reject  
16 the hypothesis.

17 CHAIRMAN FORD: So  $T_0$  on your slide VG 69  
18 is not the same as  $RT_{NDT}$ .

19 MR. KIRK: Absolutely not. No.

20 MR. HACKETT: I was going to add the  
21 Midland case was particularly an extreme example  
22 illustrating the problems you get into with  $RT_{NDT}$   
23 indexing which is one of the things we had attempted  
24 to remove from the analysis.

25 MR. KIRK: Yes. Certainly  $T_0$  is not  $RT_{NDT}$ .

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1 If that helps, I should have said it a lot sooner.

2 CHAIRMAN FORD: I thought I was a  
3 metallurgist. I'm really showing my ignorance here.  
4 Physically what is  $T_0$ ?

5 MR. KIRK: A committee decision. It's  
6 physically nothing. It's simply the temperature at  
7 which the median toughness is 100 Mega Pascal root  
8 meter. That sounded flip but it's the God's honest  
9 truth.

10 CHAIRMAN FORD: Okay.

11 MR. KIRK: The intention was you wanted to  
12 pick a temperature that is sufficiently above the  
13 lower shelf. Well, first off, that you're not getting  
14 into twining behavior. Secondly, that you've got  
15 enough slope that you can make a reliable experimental  
16 measurement, and you want to get it far enough off the  
17 upper shelf that you're not into terrine. It could  
18 have been 80 or it could have 120. Why we picked a  
19 temperature of 100 Mega Pascal root meter to combine  
20 with a reference thickness of one inch I'll never  
21 know.

22 MR. HACKETT: I think in short we could  
23 devote an entire meeting to the master curve easily.

24 CHAIRMAN FORD: I'm rapidly coming to  
25 calibration.

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1 MR. KIRK: Okay, but it's -- while we are  
2 on this point, the benefit of the master curve method,  
3 relative to  $RT_{NDT}$ , of course, is that here the index  
4 temperature is defined consistently based on toughness  
5 data for all steels. The  $T_0$  is always the temperature  
6 at which the median toughness is 100 Mega Pascal root  
7 meter.

8 Forgetting all the physical arguments, if  
9 you wish to, it's no huge surprise that  $T_0$  indexes  
10 toughness data better than  $RT_{NDT}$  which is clearly not  
11 toughness. The benefit of using  $T_0$ , in addition to  
12 all the physical underpinnings, is that it's  
13 rigorously consistent for each and every material.

14 You know the  $T_0$  and that's the point  
15 that's made at the bottom bullet is consistently  
16 defined for all steels and so it corresponds to the  
17 position of the toughness data each and every time,  
18 not to some representation of the data that is  
19 independently derived.

20 CHAIRMAN FORD: And this is true only for  
21 LEFM conditions?

22 MR. KIRK: No. Actually it's true for  
23 small scale yielding conditions which can go  
24 considerably beyond LEFM because LEFM limit in E-3.99  
25 was constructed for mathematical reasons so that

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1 linear elastic fracture mechanics would apply  
2 irrespective of material.

3           Actually, the material that set the limit  
4 was titanium. If the limit had been -- if the  
5 coefficient in the  $K_{Ic}$ , which is 2.5, had that been  
6 set on ferritic steels, it would have been set at  
7 about 1. There are a whole host of conditions and all  
8 the data points here satisfy small scale yielding  
9 conditions. You need EPFM to describe and the master  
10 curve works under those conditions.

11           CHAIRMAN FORD: Okay.

12           MR. KIRK: Next slide. Looking at  $RT_{NDT}$ ,  
13 and this is where my eyes got wide open by the process  
14 that Marjory was able to bring to the table because,  
15 like I said, I thought I understood this. Here is  
16 where I apologize for font too small. The schematic  
17 on the right-hand side of your screen shows the 10 CFR  
18 50.61 process for determining  $RT_{NDT}$ .

19           I don't wish to go into the details here  
20 but suffice it to say there's a preferred procedure  
21 which is the ASME NB-2331 procedure where you test  
22 procedure where you test Charpy, test NDTs, and  
23 compare them. Then the NRC has adopted and has used  
24 for quite sometime two alternative procedures, one  
25 involving the use of Charpy data only which is

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1 necessary to get  $RT_{NDT}$  values for plates.

2 And a second alternative involving the use  
3 of generic data which is just to say if for some  
4 reason you didn't happen to measure the  $RT_{NDT}$  of your  
5 limiting weld, oh gosh, darn, here is a generic  
6 distribution that you can go to and use a value.

7 So there are three different ways to get  
8  $RT_{NDT}$  and none of these ways is terribly prescriptive  
9 at all. Even if you go through the preferred  
10 procedure of NB-2331, it says you test Charpys, you  
11 test NDTs, and you compare them, but it's noticeably  
12 silent on how many Charpys. There's no statistical  
13 analysis of data and so on and so on and so on.

14 There are many, many engineering  
15 judgements in this process. I think I said a myriad  
16 of methods and transition temperatures have been used  
17 to define  $RT_{NDT}$ . If you go up to the MTEB 5.2  
18 procedure, which the NRC adopted in order to have  $RT_{NDT}$   
19 values for plates, you see a whole host of index  
20 temperatures used,  $T_{30}$ ,  $T_{45}$ ,  $T_{100}$ , 30 degrees off the  
21 upper shelf. All of these things go into the mirage  
22 that we call  $RT_{NDT}$ .

23 Now, having said that -- and it's been  
24 noted to me by my colleagues that I'm hypercritical of  
25  $RT_{NDT}$ , maybe because I know there is something better.

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1 Having said that,  $RT_{NDT}$  when combined with the ASME  $K_{Ic}$   
2 curve, because of the procedures you have to go  
3 through that's reflected in all these boxes to get an  
4  $RT_{NDT}$  at every point along the way, you are constrained  
5 to make only a conservative judgement. Again, in my  
6 quest to find data that violated the master curve,  
7 I've also been on a quest to find data that violates  
8 the  $K_{Ic}$  curve when indexed  $RT_{NDT}$ . I can personally tell  
9 you that that data doesn't exist.

10 The methods were set up in the early '70s  
11 with the intention of always producing a bounding  $K_{Ic}$   
12 curve, and it does. It just simply works. All of  
13 these things taken together strongly suggest that the  
14 bulk of the uncertainty in  $RT_{NDT}$  is epistemic.

15 If we had more prescriptive procedures, if  
16 we had only one procedure, if NTE and Charpy actually  
17 meant anything relative to toughness data -- I want to  
18 get Bill laughing out loud if I can -- all of these  
19 things would serve to reduce the uncertainty in  $RT_{NDT}$   
20 and those are all clearly lack of knowledge  
21 uncertainties. For the purposes of this analysis,  
22 it's pretty clear that the  $RT_{NDT}$  uncertainty should be  
23 modeled as being epistemic.

24 Actually, what I would like to do is if  
25 you would skip ahead to view graph 73 since we just

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1 talked about  $RT_{NDT}$ . If we go to view graph 73 I can  
2 show you what we've done in terms of treating the  
3 uncertainty in  $RT_{NDT}$  data. Up at the top again is the  
4 mantra, "Toughness data is truth."

5 What we did was simply to take those  
6 datasets for which we had a sufficiently well  
7 developed transition curve to have a transition curve  
8 and plotted those data as measured relative to an  $RT_{NDT}$   
9 indexed  $K_{Ic}$  curve. We then slid the curve which is  
10 represented here. It was a little more elaborate than  
11 this because we employed a statistical treatment, but  
12 we basically slid the curve until it bumped into the  
13 first data point.

14 We called that value delta RT and we  
15 adopted that delta RT value as a measure of the  
16 epistemic uncertainty in the  $RT_{NDT}$  data. That's how  
17 far off the  $K_{Ic}$  curve, which was intended to be a  
18 bounding curve was from the data it was intended to  
19 represent.

20 What you see at the bottom of the graph is  
21 a statistical representation of all of that data. We  
22 had enough data for 18 different RPV steels, both  
23 plates and welds. I think there was a forging or two  
24 in here to define delta RT values for those different  
25 materials and what this distribution tells you is that

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1 RT<sub>NDT</sub> at its worst is accurate -- I'm sorry, at its  
2 best is accurate.

3 At its worst places the K<sub>IC</sub> transition  
4 curve perhaps 175 degrees too high which is sort of  
5 getting to the Midland situation. And, of course,  
6 there is a range of situations in between.

7 What we've done in the FAVOR code, and  
8 this is by far the most significant change in terms of  
9 having an effect upon the results, perhaps not the  
10 most significant scientific change but the most  
11 significant change in terms of changing the numbers is  
12 the realization that, oh, RT<sub>NDT</sub> isn't the transition  
13 temperature, the toughness data is and here's how far  
14 off it is. In our sampling procedure, which I'll show  
15 you in a minute, what we do is we simulate an RT<sub>NDT</sub>  
16 value.

17 We then simulate a random number from zero  
18 to one and that then tells us for that run how far off  
19 RT<sub>NDT</sub> is. Like I said, it could be right, it could be  
20 175 degrees too high. On average this works out to  
21 about a 65 degree downward correction in RT<sub>NDT</sub>.

22 MR. DUDLEY: Just a minor point. How much  
23 better did you get with the three parameter fit than  
24 a two?

25 MR. KIRK: I don't know.

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1 MEMBER SHACK: Nobody uses three  
2 parameter.

3 MR. KIRK: It was a convenient fitting  
4 function. One other thing to point out because I know  
5 we've gotten this question in the past. The rules of  
6 engagement for this analysis would stick with LEFM  
7 data because the basis of FAVOR is LEFM.

8 Having said that, we did that very heavily  
9 restricted data set that we could use, as you might  
10 expect. Having said that, we have also constructed  
11 this cumulative distribution function which is shown  
12 on the bottom using EPFM data, using data that would  
13 be valid by the master curve method.

14 What we find out is what that then gives  
15 you is something more like 70 materials to put on the  
16 lower graph of a much wider variety and you get the  
17 same function. I know some concern had been expressed  
18 before that. Now the inherent assumption is that  
19 distribution represents everything. Admittedly it's  
20 a leap to say that 70 represents everything but it's  
21 a shorter leap than 18.

22 So in terms of a practical affect, that's  
23 the big change in the initiation toughness model. The  
24 other change, which is -- I'm sorry?

25 CHAIRMAN FORD: I'm struggling, I must

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1 admit. There's a whale of a lot of information here  
2 and to make sure that I'm not stamping something that  
3 is okay when I honestly don't know what I'm looking  
4 at. What other peer reviews has this gone through?

5 MR. KIRK: Okay. I would be happy to  
6 comment on that. The work that you're seeing  
7 summarized here was developed by a team that involved  
8 both myself, NRC contractors, and indeed EPRI  
9 contractors, as I pointed out.

10 We developed a draft recommendation that  
11 has been passed around to members of the industry and,  
12 indeed, members of our own contract staff, people like  
13 John Murkle have reviewed this, Randy Nanstead.

14 MR. HACKETT: And Richard Bass.

15 MR. KIRK: Richard Bass at Oak Ridge  
16 National Laboratory. This has been through -- in that  
17 group I lot track of my revision count. We went back  
18 and forth.

19 CHAIRMAN FORD: And how about the ASTM  
20 bodies?

21 MR. HACKETT: The ASTM standard has been -  
22 - I don't know, again, how many versions that went  
23 through. Several of us were involved in that. Mark  
24 has been more involved than most. It started in the  
25 late '80s and refined into a standard in -- when was

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1 it, '97?

2 MR. KIRK: Yes, ASTM has adopted the  
3 master curve testing standard in 1997 so they provided  
4 us with a method to measure  $T_0$ . In that committee, as  
5 you might expect the notion of the universal curve  
6 shape. Everybody is going, "What?" Universal  
7 scatter. "What?" That was vetted through that  
8 committee.

9 Then following that in 1998 ASME adopted  
10 a parameter called RT  $T_0$ , which is simply  $T_0$  plus 35  
11 degrees fahrenheit as an alternative to  $RT_{NDT}$  to index  
12 the  $K_{Ic}$  curve. On the outside -- well, external to  
13 this project the master curve itself has gone through  
14 considerable peer review in both ASTM and ASME.

15 Here, to be honest, and this is where the  
16 initial constraint came in, I said we didn't want --  
17 well, we didn't want to if we didn't have to require  
18 the licensees to make new measurements.

19 As we were discussing yesterday, when you  
20 are dealing with uncertainty and, indeed, this is a  
21 huge uncertainty, two things you can do. One is to  
22 try to mathematically account for it which is what  
23 we've done here. The benefit is that enables you to  
24 use your old measurements. The detriment is you are  
25 introducing that level of uncertainty.

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1           The alternative would be to say, well,  
2           let's go make toughness measurements and do this  
3           better but that would send everybody scurrying back to  
4           reconstitute Charpys and preprac them and test them  
5           and hopefully find them in the hot cells.

6           That is certainly a further improvement  
7           than can be made here. Indeed, I know a number of the  
8           licensees are interested in that level of improvement.  
9           That's not one that we've taken here.

10           CHAIRMAN FORD: Okay. All of these, as  
11           you said, at the very beginning, using a 95 percentile  
12           you are going to come up with the end result.

13           MR. KIRK: No. You're going back to the  
14           graph that Ed showed. In this we have quantified --  
15           well, first off -- you told me I was going to get in  
16           trouble for that and you were right. We used the 95th  
17           percentile for convenience. I think your comment  
18           about a one sigma representation is one that I've  
19           taken note of.

20           Throughout here we are defining  
21           distributions left and right. In this presentation  
22           you're probably not going to be able to keep track of  
23           them. But what you'll find out if you refer to our  
24           draft NUREG which is the basis for this if you refer  
25           to the FAVOR theory manual which shows you what

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1 actually got in there is that we only truncate the  
2 distributions when it results in a physically  
3 unrealistic prediction like a negative transition  
4 temperature shift.

5 I mean, that's not relevant here but, for  
6 example. No, we've put the full probability  
7 distributions into the paper code.

8 CHAIRMAN FORD: Okay.

9 MR. HACKETT: I guess I would just add a  
10 comment just sort of almost a philosophical basis  
11 here. The buy-in you need for this project on the  
12 master curve is really fairly limited, as Mark tried  
13 to get to. I mean --

14 MEMBER SHACK: No. You need to believe  
15 it's the truth.

16 MR. HACKETT: That's what I was coming to.  
17 What you are really buying into in this project, and  
18 that's why I just wanted to try and make sure the  
19 record is straight on this thing, is that the master  
20 curve in  $T_0$  is giving you a better representation of  
21 the real material behavior than  $RT_{NDT}$  for all these  
22 variety of reasons we've been through.

23 Given that, there are whole other levels  
24 of things you can do with a master curve concept. I  
25 think it's also fair to say it's been an area that's

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1       been guilty of some zealotry over time in selling it.  
2       But it had to go through a vetting process which I  
3       think it largely has been through in terms of ASTM and  
4       ASME.

5                    But for application to this project what  
6       you are really saying is that has given you better  
7       representation of what is the truth for these ferritic  
8       materials. Then we are making adjustments to take  
9       that conservative bias out, as Mark mentioned, in the  
10      RT<sub>NDT</sub> methodologies. I think that is really all it  
11      boils down to for this go-round.

12                   MEMBER SHACK: Well, that and that your 18  
13      material curve augmented by your 70 is universal.

14                   MR. KIRK: Yes.

15                   MR. HACKETT: Yes.

16                   MR. KIRK: And really what that curve  
17      represents is nothing more than quantifying what all  
18      -- I've got to remember I can't point at the screen --  
19      what all of this gave you. What all of that  
20      combination of judgements and guidance or lack of  
21      guidance produces.

22                   Indeed, at the beginning of the project it  
23      had originally been the hope that we could use, and we  
24      have used some of these diagrams directly as  
25      mathematical models. In this case it was much easier,

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1 much more pragmatic just to rely on the data to tell  
2 us what the end result was because propagating all  
3 that through just became impossible.

4           Okay. So we've now discussed in detail  
5 one of the parameters which was the index temperature,  
6  $RT_{NDT}$ . We can now go on to just briefly discuss  $K_{Ic}$ .  
7 In terms of significance, this -- well, let me get to  
8 the end. The physical understanding of the cleavage  
9 fracture process shows us that the noncoherent  
10 particles and other barriers that present themselves  
11 to dislocation motion are alone responsible for the  
12 scatter in  $K_{Ic}$ .

13           That idea coupled with a number of other  
14 ideas, mainly that  $K_{Ic}$  does not exist as a point  
15 property. That is to say, all  $K_{Ic}$  values have  
16 associated with the milane scale, and that is the  
17 crack front length as it is commonly known, suggest  
18 that there is only so good that you can measure  $K_{Ic}$ .

19           In other words, I suppose as an  
20 experimentalist I like this analogy if we had  
21 perfectly machine specimens preprac to exactly the  
22 same depth, all tested exactly the same way, you would  
23 still get the scatter that alarms most non-  
24 metallurgist when you look at this plots.

25           So that understanding tells us that in a

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1 PRA context this uncertainty that you see here is  
2 indeed irreducible and, therefore, should be modeled  
3 as aleatory, which is to say this created -- I think  
4 this consumed probably about two months of Terry  
5 Dickson's life.

6 In the old version of FAVOR we did an  
7 epistemic model of  $K_{Ic}$  where we went through our  
8 toughness model and we got an applied K at a  
9 particular time, temperature, pressure. Then we drew  
10 randomly from the  $K_{Ic}$  distribution at that  
11 temperature. We said K applied,  $K_{Ic}$  passed, failed,  
12 zero, one binary.

13 Whereas now, and Terry will get into this  
14 in much more detail tomorrow, we recognize that for  
15 any applied  $K_{Ic}$  that is, in fact, presented to a  
16 material which has a distribution of  $K_{Ic}$  value so  
17 instead of for that given applied  $K_{Ic}$  instead of the  
18 material having failed or not, what we calculate and  
19 indeed carry through the model is some probability of  
20 failure.

21 Instead of having zeros and ones we've got  
22 .005s or whatever that then get added up. That was a  
23 significant programming change which is indeed a much  
24 better -- is consistent with the PRA process, is a  
25 much better representation of the physics. What

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1 effect that has had on the numbers I honestly couldn't  
2 tell you because we haven't done nor would intend to  
3 do that comparison.

4 MEMBER SHACK: One thing is when you come  
5 up with the aleatory model for  $K_{Ic}$  and you do it this  
6 way, you get the three significant figures, the same  
7 numbers that Oak Ridge got from their statistical  
8 analysis which I thought was based on  $RT_{NDT}$ .

9 MR. KIRK: I'm sorry?

10 MEMBER SHACK: You have a Weibull model  
11 for  $K_{Ic}$ , an aleatory distribution. That describes the  
12 aleatory behavior of  $K_{Ic}$ .

13 MR. KIRK: Right.

14 MEMBER SHACK: That's a Weibull model. So  
15 say three significant figures I get the same  
16 coefficients in there that I got from the Oak Ridge  
17 model when I did it with  $RT_{NDT}$  that you're doing with  
18  $RT$  lower bound.

19 MR. KIRK: Okay. Let me --

20 MEMBER SHACK: There is something magical  
21 I'm missing here.

22 MR. KIRK: I think let me clarify. First  
23 off, the aleatory model, the other mantra that we kept  
24 having in this project was physically motivated and  
25 empirically derived, which is to say we got from the

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1 underlying physics the notion that there should be an  
2 exponential temperature dependence in  $K_{Ic}$ . It should  
3 have a lower bound value.

4           Indeed, we took out of the physics that  
5 the scatter in the Weibull slope should be four. But  
6 having said that, we then fit the temperature  
7 dependency. We fit the lower bound values because we  
8 didn't have independent estimates from the -- or  
9 direct estimates, I should say, from the physics of  
10 that.

11           The reason why the numbers are the same is  
12 that we didn't have independent numbers from the  
13 physical model. They, in fact, came from the data.  
14 The other thing that perhaps isn't clear is Oak Ridge  
15 wasn't fitting  $RT_{NDT}$  data. They were fitting RT lower  
16 bound data. The index temperature they used was RT  
17 lower bound.

18           MEMBER SHACK: Well, that confused me  
19 because when I looked in the Oak Ridge manual, the  
20 first time it comes up, of course, it's fit to  $RT_{NDT}$ .  
21 Then they tell me, okay, that's really just, you know,  
22 an approximation. I thought in the original fit --

23           MR. KIRK: In the original fit, yes.

24           MEMBER SHACK: -- it was  $RT_{NDT}$ . Did the  
25 numbers change?

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1 MR. KIRK: The numbers changed. And you  
2 may have found an error in our work in terms of  
3 labeling. Right now the --

4 MEMBER SHACK: They sort of warn me as I  
5 go along here that that is only approximate first up.  
6 I figured that was just to trap the reader.

7 MR. KIRK: No, the fit --

8 MEMBER SHACK: Okay. The original fit  
9 really was different, as I would have expected it to  
10 be.

11 MR. KIRK: The original fit really was  
12 different. Indeed, this gets into some of the, well,  
13 to me the interesting nuances of why it was good to  
14 have the physical model and the empirical models.

15 When we got to -- when you did just the  
16 the empirical fit of the data, you found it doing  
17 bizarre and unexpected things like the scatter on the  
18 lower shelf was bigger than the scatter on the upper  
19 shelf. That was simply an artifact when you fit it  
20 versus  $RT_{\text{NDT}}$ . That was simply an artifact of the fact  
21 that you didn't have enough data on the upper shelf  
22 and you didn't have enough data to independently  
23 estimate the scatter parameter.

24 So bringing in the elements of the  
25 physical knowledge that said, well, first off,  $RT_{\text{NDT}}$

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1 isn't the right X-axis normalization. We need to have  
2 something tied to the data. That is physical  
3 observation No. 1.

4           Combine that with the notion that there  
5 should be a scatter parameter or Weibull slope that is  
6 not only universal to the various materials but  
7 constant with temperature. Put those two physically  
8 motivated constraints on the model and you get out --  
9 I don't know if I can blow this up so that you can  
10 actually see it.

11           You get a  $K_{Ic}$  versus temperature model  
12 that is in agreement with the physics, is in agreement  
13 with what you would "expect it to do" which is to say  
14 smaller scatter on the lower shelf, expanding scatter  
15 as we go up.

16           MR. HACKETT:       It's an interesting  
17 question. I'll just add one more comment. This goes  
18 to the root of someone. Mike Mayfield started us down  
19 this path many years ago before there was a master  
20 curve. If you ask yourself the question, "What if I  
21 had never heard of a master curve or there wasn't such  
22 a thing, what would I have done in this area?"

23           I think his vision at the time was as  
24 simple as we're just going to get all the appropriate  
25 data and analyze it the best way we know how

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1 statistically and at least try to have a statistically  
2 motivated version of this that wouldn't necessarily  
3 have the physical underpinnings that Mark is talking  
4 about. But would that have been an improvement?  
5 Yeah, absolutely it would have been an improvement.  
6 You didn't need the master curve to do this.

7 It's a refinement that came along in  
8 parallel that I think made some things better from a  
9 physical understanding basis in addition to some of  
10 what was going on in the project anyway. There would  
11 have been improvements here I think regardless of the  
12 different form.

13 MR. KIRK: Did that answer your question,  
14 though?

15 MEMBER SHACK: Yes.

16 MR. KIRK: Okay.

17 MEMBER SHACK: I'm just trying to --  
18 coming back to Ed's point, what difference would it  
19 make in the final? I mean, if I lump all the aleatory  
20 and epistemic things together, would it make a  
21 difference?

22 MR. HACKETT: We have not done that in any  
23 kind of systematic way. That's not to say we couldn't,  
24 although we weren't in the mode of searching for --

25 MEMBER SHACK: It certainly makes it

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1 easier to understand the Oak Ridge calculation when  
2 you draw an epistemic loop and aleatory loop inside.

3 MR. HACKETT: Yes.

4 MEMBER SHACK: And that alone is almost  
5 worth the price of admission.

6 MR. KIRK: I think -- I've gone through  
7 this debate many times with people who were all  
8 trained as engineers so we are all trained to say,  
9 "Does it make a difference?" For my money, certainly  
10 you want to focus on the things that are most  
11 important unquestionably.

12 But there is also considerable value in  
13 doing things right, especially from a regulatory  
14 perspective where you get yourself caught in this trap  
15 of, "Oh, well. I don't know. Let's make it  
16 conservative." That becomes an increasingly in  
17 today's world a hard judgement to defend. If  
18 conversely you can say this is physically the right  
19 thing to do, it makes it much more defensible.

20 Indeed, it's then something -- the best  
21 part about that is I think it sends something that you  
22 can change later as your state of knowledge improves  
23 because you know why you made the decision and you  
24 know where it came in.

25 MEMBER SHACK: If you lump them together,

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1 I'm not sure that you would have been able to do the  
2 conditional probability of fracture. That is, that  
3 would have included both aleatory and epistemic  
4 uncertainties and that really would have been wrong.

5 MR. KIRK: Well, yeah. And certainly if  
6 you lump together you truly haven't gained that much.  
7 I'll have to take exception with Ed because the  
8 original ASME  $K_{Ic}/K_{Ia}$  analysis was not a statistical  
9 analysis. That clearly needed to be done. But if you  
10 just do a statistical analysis of  $RT_{NDT}$ , you're stuck.  
11 Your hands are tied and you're saying  $RT_{NDT}$  is truth.

12 Now you're stuck with something that  
13 clearly is not truth most of the time and you wouldn't  
14 have gotten the 65 degree benefit and the conditional  
15 probability failure numbers would have been at least  
16 one order of magnitude higher. I'm saying that with  
17 a fair degree of certainty because it was only  
18 recently that Terry implemented this adjustment for  
19 epistemic uncertainty in the code.

20 Indeed, the original Oconee scoping  
21 analysis was done without that adjustment in because  
22 we didn't have it at the time. When Terry put it in,  
23 fortunately or unfortunately, I don't know, this isn't  
24 something we have taken the time to document. I  
25 recall phone conversations where the comment was made

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1 that that change alone drove the failure probabilities  
2 down by at least an order of magnitude.

3 Certainly any licensee that is watching  
4 their  $RT_{PTS}$  number knows that if they can get, heck, 5  
5 degrees fahrenheit is great. 65 degrees fahrenheit  
6 you just forget that you have a problem anymore.  
7 There is no question in my mind that a purely  
8 statistical analysis would not have netted that  
9 benefit because you would be stuck with the notion  
10 that  $RT_{NDT}$  is truth. You just can't get there from  
11 here.

12 MR. HACKETT: You can see what happens  
13 when you get materials and mechanics people going on  
14 this stuff. We're going to run out of our time.

15 CHAIRMAN FORD: I'm looking at the time.  
16 I don't want to stop the flow of concentration here.  
17 We can go until half past 12:00 before we stop. I  
18 don't believe there is any reason why we can't do  
19 that. Ed, I'll leave it up to you to decide when we  
20 stop for lunch.

21 MR. HACKETT: I guess I don't see this yet  
22 as a good point to stop but I might ask Mark to look  
23 at an intermediate juncture.

24 MR. KIRK: We can -- well, I think we have  
25 essentially finished the initiation toughness model.

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1 We've got a couple more logical break points. We need  
2 to work through the irradiation shift model and the  
3 arrest toughness model. If we can do those two in the  
4 next half hour, that will probably be pretty good.

5 MR. HACKETT: I'd be thinking you could  
6 probably do one.

7 MR. KIRK: Hopefully.

8 CHAIRMAN FORD: I was hoping for lunchtime  
9 to try to catch up.

10 MR. HACKETT: This could be a good break  
11 point since we've since debated the master curve a lot  
12 and talked about the initiation toughness model.  
13 We're at the next jump-off point which is the  
14 irradiation model

15 CHAIRMAN FORD: If you don't mind.

16 MR. KIRK: That's fine.

17 CHAIRMAN FORD: We'll break now. That  
18 gives me an hour to try and catch up here.

19 MR. HACKETT: Drinking from the fire hose.

20 CHAIRMAN FORD: This is one of those  
21 situations I say now I'm a corrosion engineer rather  
22 than a metallurgist. We'll recess for an hour and  
23 come back at 1:00.

24 (Whereupon, at 11:59 a.m. the meeting was  
25 adjourned for lunch to reconvene at 1:00 p.m.)

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