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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

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_{NDT} 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

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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 Oconee. 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: Were 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 Ocone
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 Ocone 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 probabilistic 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, Poison'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 defamation 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 seals. 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_{NDT} at its worst is accurate -- I'm sorry, at its
2 best is accurate.

3 At its worst places the K_{IC} 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_{NDT} 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_{NDT}
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_{NDT} 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_{NDT}.

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_{NDT} 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_{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_{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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