Official Transcript of Proceedings ACRST-3164

NUCLEAR REGULATORY COMMISSION

ORIGINAL

Title: Advisory Committee on Reactor Safeguards Joint Meeting of Materials & Metallurgy and Plant Operations Subcommittees

PROCESS USING ADAMS
TEMPLATE: ACRS/ACNW-005

Docket Number: (Not Applicable)

Location: Rockville, Maryland

Date: Tuesday, July 10, 2001

Work Order No.: NRC-312

Pages 1-274

TR04

NEAL R. GROSS AND CO., INC.
Court Reporters and Transcribers
1323 Rhode Island Avenue, N.W.
Washington, D.C. 20005
(202) 234-4433

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

+ + + + +

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

+ + + + +

JOINT MEETING OF MATERIALS & METALLURGY AND

PLANT OPERATIONS SUBCOMMITTEES

+ + + + +

TUESDAY,

JULY 10, 2001

+ + + + +

ROCKVILLE, MARYLAND

+ + + + +

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

COMMITTEE MEMBERS:

F. PETER FORD	Chairman
MARIO V. BONACA	Member
THOMAS S. KRESS	Member
GRAHAM M. LEITCH	Member
STEPHEN ROSEN	Member
WILLIAM J. SHACK (Recused)	
JOHN D. SIEBER	Member
ROBERT E. UHRIG	Member
GRAHAM B. WALLIS	Member

I-N-D-E-X

AGENDA ITEM	PAGE
Introductory Remarks by Subcommittee Chair	3
Industry Perspectives, Larry Matthews, et al.	4
NRC Staff Presentation	
Introduction, Jack Strosnider, NRR	154
Technical Discussion & Actions Allen Hiser, NRR	157
Risk Perspective, Mark Reinhart, NRR	212
Staff Perspective Including Input From "Independent Group of Experts," Ed Hackett, RES	227
Regulatory Process, Tad Marsh, NRR	249
Summary, Jack Strosnider, NRR	257
General Discussion and Adjournment	257

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

(8:32 a.m.)

CHAIRMAN FORD: The meeting will come to order. These are Joint Subcommittees on Materials & Metallurgy and Plant Operations.

I am Peter Ford, the Vice Chairman of the Materials & Metallurgy Subcommittee. ACRS Members in attendance are, or will be: Dr. George Apostolakis; Dr. Mario Bonaca; Dr. Thomas Kress; Mr. Graham Leitch; Mr. Stephen Rosen; Mr. John Sieber; Dr. Graham Wallis; and Dr. Robert Uhrig.

The purpose of this meeting is to discuss the controller rod drive mechanism, CRDM, cracking issue and materials reliability program. This is our first subcommittee meeting on this issue.

Ms. Maggalean W. Weston is the cognizant ACRS staff engineer for this meeting. The rules for participation in today's meeting have been announced as part of the notice of this meeting published in the Federal Register on June 27, 2001. A transcript of the meeting is being kept and will be made available, as stated in the Federal Register notice.

It is requested that speakers use one of the microphones, identify themselves, and speak with sufficient clarity and volume so that they can be readily heard.

We have received no written comments from members of the public regarding today's meeting. A portion of this morning's session may be closed pursuant to 5 U.S.C. 552b(c)(4) to discuss proprietary information.

Dr. William Shack will recuse himself from this subcommittee meeting discussion because of a conflict of interest. Similarly, Mr. Stephen Rosen will recuse himself from discussions specific to Duke Power Company because of a conflict of interest.

We will now proceed with the meeting. Mr. Larry Matthews, representing the Materials Reliability Program, will introduce the topic and the presenters.

MR. MATTHEWS: Good morning. I am Larry Matthews with Southern Nuclear Operating Company. I am the Chairman of the Alloy 600 Issues Task Group of the Materials and Liability Project. I will be doing most of the presentation. I have a little back-up over here in case we get into things that I clearly don't understand.

(Slide change)

MR. MATTHEWS: The MRP's purpose, being here -- Those are our industry goals. In the near term, what we want to do is to assure the structural integrity of our plants. In the longer term, we want to work toward developing a program so that the utilities can effectively manage PWSCC in their units.

We will be explaining the background. We have been asked to go over the background of the head penetration issue, present our program, and then we will get into what our recommendations for the industry are.

I have a lot of slides. So in case we don't get to it, I am going to put the conclusions up first.

(Slide change)

MR. MATTHEWS: Basically, we have been working on this issue for a while, and Axial PWSCC -- that is, cracks in the axial direction in the CRDMs, we feel, do not impact plant safety if they are only Axial cracks. They are bounded by the previously submitted safety analyses back in the '93/'94 time frame.

We also feel there is reasonable assurance that other PWRs do not have circumferential cracking that would exceed the structural margin. This is based on Oconee-1 and ANO-1, which have had these cracks, being in the highest grouping based on an effective time-at-temperature for their heads.

These leaks were discovered by careful visual examination of their heads. Volumetric examination of other nozzles in those plants in Oconee have found only some minor craze cracking, nothing of real significance.

The leaks were discovered when there was still plenty of structural margin remaining, and several other plants that are in the highest groupings have examined their heads and had no evidence of leakage at this point.

CHAIRMAN FORD: Mr. Matthews, before you come off that graph, could you put it back, please?

MR. MATTHEWS: Sure.

CHAIRMAN FORD: When you are talking about Oconee and ANO being in the highest grouping, that is in the United States. Were you also be doing a reference to other incidences abroad?

MR. MATTHEWS: We have not benchmarked what we have done so far against the other foreign plants. There's a lot of differences between the way the plants in the U.S. were made and the ones overseas, and so we are not sure that putting them on the same graph is the right thing to do.

We will probably be taking a look at it, but we haven't done that today.

(Slide change)

MR. MATTHEWS: We have other activities going on in the MRP. We are working on a risk assessment of the overall problem. We've got some probabilistic fracture mechanics work that is getting underway.

We will be assessing crack growth data and what data is available and where there are needs to further establish crack growth data. We will be working on NDE demonstrations, both designing a block and fabricating the block for demonstrating NDE capabilities and also developing the techniques and demonstrating what the techniques are capable of detecting.

We are putting together information and training package for utilities to use for training of their people who will be doing the visual examinations of the head, working on flaw evaluation guidelines and reviewing repair and mitigation strategies.

CHAIRMAN FORD: Before you take that one off, I take it all of these will be addressed as we go through. These are conclusions, and the supporting data for all of these will be given later on?

MR. MATTHEWS: These are activities we have ongoing right ow. There's not a lot of results to bring forth on these activities right here. They are underway.

CHAIRMAN FORD: And what is your time scale, and what do you hope to achieve in that time scale?

MR. MATTHEWS: As fast as possible. We have NDE. We are hoping to have at least an initial block built to demonstrate the capabilities before the fall outages. So a risk assessment is underway and should be through fairly quickly, I would think.

CHAIRMAN FORD: So should you find more cracks in other stations during the fall outages, you will have a sufficient amount of good quality data -- for instance, crack growth data, etcetera -- to substantiate your safety arguments?

MR. MATTHEWS: We think so. The crack growth team is going to meet. First meeting is in August, and that is in here. But if there's more data needed, it takes time to generate that data, and we'll just have to go with what data is available and conservatisms, etcetera.

(Slide change)

MR. MATTHEWS: So we know what we are talking about, this is a diagram of the vessel head. This particular one is in the B&W unit. You have the head. Penetrations come through the head, and they are welded -- you'll get a little more detail on the next slide -- with a J-grove weld on the ID.

The B&W units are -- or actually, only two units, the Oconee-1 and TMI have these thermocouple penetrations out on the very edge. This is the insulation that -- Most of the B&W units have insulation above the head that sits up above the head in a flat plane.

There's a shroud out here, and we'll get into some of the details of what other people have done. Other units have differing configurations on this insulation, and makes it harder for many of them to do a good visual, but we'll get into some of that.

CHAIRMAN FORD: So when you said earlier on that you couldn't take into account the French experience because of differences in design, how are they markedly different?

MR. MATTHEWS: Not necessarily designed, but as much the material processing. How you process the alloy-600 makes a big difference, and we believe they process their tubes considerably differently. I believe they actually even have counter bores on the ID that none of the U.S. plants have, and things like that.

CHAIRMAN FORD: I'm just concerned that we are throwing out a whole lot of data, an awful lot of data.

MR. MATTHEWS: We are not throwing it out. It's certainly going to be taken into account. Right now, what we are trying to do, though, is just rank the U.S. plants and figure out what we need to do in the immediate near term for the U.S. plants. All of that information is going to be folded into the program, for sure.

DR. WALLIS: Well, the plants with the access holes get inspection without much trouble, presumably.

MR. MATTHEWS: Some of the B&W units have cut access holes right here that are large holes, that are like nine-inch or maybe even 12-inch holes. I'm not exactly sure of the size. They can open those doors and quite easily look --

DR. WALLIS: They can see right in there.

MR. MATTHEWS: -- and see all of this. The B&W units that have not cut the access holes have what they call mouse holes, which are small holes down at the bottom of the shroud that they can put video probes or other techniques for getting under there.

DR. WALLIS: So you don't need to take the insulation off and all that sort of thing.

MR. MATTHEWS: No, not for these plants.

DR. WALLIS: But for all plants, you've got some sort of hole you can snake something in.

MR. MATTHEWS: That's not true, and I'll show you some of that.

CHAIRMAN FORD: Is that the only detection technique you use?

MR. MATTHEWS: Right now, that was the one we were recommending. We have other NDE that we are looking at and evaluating. None of it has been qualified.

We had qualified techniques for detecting a different type of flaw, the ID initiated flaw that the French had seen, and we had qualified techniques for doing that, and actually, plants were on a schedule to do inspections of the lead plants anyway, of their penetrations for the ID initiated flaw.

These flaws are different. It takes different techniques to detect them, and the way that we've seen first it shows up is through leakage. That's the quickest way to verify whether or not you've got leakage. It doesn't tell you whether they are through a crack, and we understand that.

DR. WALLIS: Well, this is a box. If it's boxed in, you would think that a leakage would simply increase the partial pressure of steam in there to the point where you would be able to detect it somehow.

MR. MATTHEWS: I'll show you some pictures. This is not a pressure chamber.

DR. WALLIS: No, you detect water vapor in there.

DR. MATTHEWS: It's very, very low leakage, very low leakage.

DR. WALLIS: It's got nowhere to go. So it stays in there.

CHAIRMAN FORD: We will be coming back to discussing later on in this presentation the whole question of NDE and its accuracy and where we are expected to be in the fall?

MR. MATTHEWS: We'll get to some of that, what we are trying to do anyway.

(Slide change)

MR. MATTHEWS: This is a simplified diagram of the head penetration. It shows the J-groove weld where the tube itself is welded to the ID of the head, and the angle of incidence here depends on where it is on the spherical head.

This is again a B&W design. They have -- Their CRDMs are flanged on. The Westinghouse and other units are different. They are screwed on and sealed with a canopy seal weld, not as easy to remove even the CRDM.

(Slide change)

MR. MATTHEWS: Speaking of the French --

DR. WALLIS: This weld is what retains the tube or is it retained some other way?

MR. MATTHEWS: Yes. That's the retention of the tub, is that J-groove weld on the ID of the head.

DR. WALLIS: So if the weld fell completely, the tube comes out?

MR. MATTHEWS: If it fails in a circumferential direction right at the interface with the tube, it would. But most of the flaws tend to be radial, in which case it will not eject under that situation at all.

Bugey found their first crack, we believe in '91, an ID initiated, through-wall crack. By the way, there's a lot of background here. If I'm boring any of you or you're already familiar with it, then I can skip through some of this.

Later on, a lack of fusion was detected in the attachment weld, a small lack of fusion at Ringhals-2 in '92.

DR. WALLIS: These are both outside the United States?

MR. MATTHEWS: Yes. Industry safety assessments for the U.S. were prepared in the early Nineties for those types of cracking, and concluded it was not an immediate safety issue.

Additional European PWRs over the years have discovered their cracks -- axial penetration cracks in their penetrations, and they have initiated head replacements at many units. In 1991 DC Cook --

DR. WALLIS: Initiated head replacements? They have actually done that?

MR. MATTHEWS: Oh, yes. They have replaced many heads.

DR. WALLIS: So it's not just initiated? They have gone ahead --

MR. MATTHEWS: Well, they haven't finished. There are some heads that have not been replaced.

DR. WALLIS: It takes a long time, yes.

MR. MATTHEWS: You can't order one and have it tomorrow.

In '94 Cook 2 found one penetration that had axial cracks in it, and that penetration was repaired, and the owners groups over the years have been working with models, etcetera, trying to help the utilities manage the issue.

DR. WALLIS: Have the -- During this time period, were the NRC involved at all? When you say an industry program --

(Slide change)

MR. MATTHEWS: Yes. The NRC was involved. In 1997 they issued Generic Letter 97-01, requested quite a bit of information. The owners group -- all the owners groups wound up putting together generic responses, and those were coordinated between the owners groups through an NEI task force.

We wound up with a way to rank the plants in the U.S. based on this type of ID initiated flaw. That was a histogram, and there were a couple of models, and this way that we have normalized everything that Cook 2 allowed us to rank the plans on the same scale, even though they were using different models.

CHAIRMAN FORD: On the basis of one data point?

MR. MATTHEWS: That was the normalization for ranking them. The models predicted various times of degradation, and then --

CHAIRMAN FORD: This, I guess, will be

coming on later. So am I being superfluous to ask you what the basis for these prediction models were back in that time period? Are you going to cover that later on?

MR. MATTHEWS: Well, no, this is about all I was going to say about those models, except that they are probably still pretty good for what they were set up to do on the initiated flaws, and that they were using time and temperature. They were using material properties and stresses that were calculated, operating in residual stresses for predicting the initiation and the crack growth rate, based on the material properties, etcetera.

CHAIRMAN FORD: You've given only one data point. That's the only thing against which the model was --

MR. MATTHEWS: I think the French data was actually used in some of these, and there were other data points, if you will. The lack of cracks was also a data point that could be used in some.

CHAIRMAN FORD: Just something greater than a certain time period?

MR. MATTHEWS: Yes.

DR. WALLIS: Did the NRC do independent modeling?

MR. MATTHEWS: You have to ask the NRC. I don't believe they did, no.

MR. BAMFORD: Let me say something briefly about the model. I'm Warren Bamford from Westinghouse.

We were involved in setting up a number of different models, starting around 1992 or thereabouts. We began by benchmarking with European experience, which was Ringhals plant where it was the first non-French plant that had cracked, and it -- Cracking was found there in '92 or thereabouts, I think.

So the first model benchmark with the Ringhals experience. As time went on, we found a flaw at the DC Cook plant in the U.S., and we revised the model to be consistent with experience up to that date, and benchmarked everything in comparison with the DC Cook plant.

The reason for that was that that's the American experience, and we thought that that would be more relevant to the plants in the U.S.

So the modeling has gone on and has been continually upgraded with time, but it wasn't until this past fall that we got involved with -- or that we saw cracks in other locations, originating in other locations other than the inside surface of the tube.

We are not aware of cracking anywhere else in the world that's originated at any other location other than the inside of the tube except for the plants that we are going to be talking with you about here. So that's another reason why we try to stay with the U.S. plants in our modeling right now.

Now you could also argue that plants outside the U.S. haven't found any cracks other than the inside area of the tube because they haven't looked. That's not entirely true, but you have to -- I guess we have to admit that not everyone has looked as completely in the outside of the tube and at the weld region as we are doing now.

So I think that's the reason why the model has been changed. The other thing that happened was the cracking that we see now since last fall doesn't appear to be focused on the outer rings of the head where the stresses are the highest from an operational point of view, and that's why we changed out model to just be time and temperature.

So I hope that helps a little bit, because he's going to get in a little bit more. That's a little more background.

CHAIRMAN FORD: Just to follow on from your comment, you know, as I understand it from one of your earlier reports, MRP reports, in the table there you were showing several thousand inspections --

MR. MATTHEWS: Yes.

CHAIRMAN FORD: -- in France, from which --

MR. BAMFORD: Worldwide.

MR. MATTHEWS: It's worldwide.

CHAIRMAN FORD: Oh, yes, I recognize that, but I'm just thinking of one country and, therefore, procedure. So you've got a lot of experience there, and you're saying for some reason you were not able to use that data to calibrate your prediction model that you had at that time?

MR. BAMFORD: We have not done that at the present time.

CHAIRMAN FORD: Is there a technical reason for not doing that?

MR. BAMFORD: Well, the French have not seen cracking on the OD and at the --

MR. MATTHEWS; No, he's talking about the old model, the 97-01 model. And the data was -- I guess the data and the materials and stuff was all part of the models that were built back in the Nineties.

MR. HUNT: Larry, this is Steve Hunt with

Dominion Engineering. I worked on some of the models for EPRI.

We did inspections at a number of plants in the Untied States, including Oconee, Oconee-2. We inspected all the nozzles back in the early 1990s. Some nozzles had some very shallow cracks, and they were reinspected several times to try to track that.

We also performed inspections at Ginna and Millstone and Point Beach, and we didn't find the same extent of cracking as was being found in France. As a result, we were benchmarking the models to U.S. plant experience, which was about five or six plants of data that we had, and the models then were adjusted for differences in stress and that type of thing. But they were all focused on the inside surface where all the cracking had been worldwide up until this point.

So it wasn't just one plant, one data point at DC Cook. It was, in fact, five plants that were used, including repeat inspections at one of the units.

CHAIRMAN FORD: The reason why I keep hammering away at this is that these are in your conclusions. I suspect you're going to come to some argument, that we might not expect cracks for a certain time period. That is presumably based on some data and a model, and this is why I keep asking this question. What is your basis, technical basis, factual basis, for saying this?

That's why I keep asking this question.

MR. MATTHEWS: All right.

DR. WALLIS: Are we going to see what these models are or is there some way that --

MR. MATTHEWS: It's pretty simple, the one we are using right now to rank the plants.

DR. WALLIS: Is it just a sort of a curve fitted through a point or does it have some more sophistication?

MR. MATTHEWS: What we've done is calculated the effective time at temperature, and I'll get into the details here, of the heads.

DR. WALLIS: I don't know we need to get into it, but we could get into details if we wanted to. There's a record.

MR. MATTHEWS: Yes. Of the model? There was a pretty good description of the -- Calling it a model might not even be appropriate at this point for what we are doing for the OD initiated cracking that we've seen recently.

CHAIRMAN FORD: So it's essentially -- You mentioned inputs to the model would be temperature --

that was one of the prime ones.

MR. MATTHEWS: Yes. Temperature and effective --

CHAIRMAN FORD: And material and fabrication.

MR. MATTHEWS: No, not now. Just a simple Arrhenius model, time and temperature. That's all we are using right now to rank the plants, time and temperature, because the models we had before didn't predict this kind of cracking that we are seeing. They weren't set up to normalize and use --

CHAIRMAN FORD: So the temperature using a given activation enthalpy is the -- That's it?

MR. MATTHEWS: Yes, the head temperature and the time that the plant has operated.

CHAIRMAN FORD: But we know -- Maybe I'm jumping the gun here. If I'm jumping the gun, tell me to stop, and you'll get to it later on.

MR. MATTHEWS: I'll get to some of this, but go ahead.

CHAIRMAN FORD: But we know that there are heats and material that crack and other ones don't and, as far as I know, we don't know why some are bad and some are good.

MR. MATTHEWS: Exactly, and --

CHAIRMAN FORD: And why some could be even worse, which is from the safety point of view.

MR. MATTHEWS: You know, we are not saying nothing is worse, and we are trying to account for some of that in the uncertainty and the time period that we are telling people they need to go inspect. But just normalizing all the plants to Oconee-3 on time and temperature -- basically, the assumption there is everybody is exactly as bad but no worse than Oconee as far as material properties and stresses or whatever else is driving the OD initiated cracking.

CHAIRMAN FORD: Okay.

MR. MATTHEWS: We have already covered the rest of that.

(Slide change)

MR. MATTHEWS: This was just basically the histogram that the industry put together based on 97-01 response. We had ranked all the plants normalized to the time that they would reach a probability of a 75 percent through-wall flaw that was equivalent to Cook-2 when they did their inspection.

The short bar is those plants that would have reached equivalence to Oconee-2 within five -- effective five years. The next one was five to 15, and the next one with all the plants that would have reached it after 15 years.

CHAIRMAN FORD: So most of them have no plans, and it looks as if the bars are so narrow, you're talking about just two or three plants that had plans to do anything that were over 15 years.

MR. MATTHEWS: At that point in time, that was the plans. Those dark shaded bars were -- or I guess they are red on the graph there -- had announced plans to do inspections at some point in time. The white --

CHAIRMAN FORD: It looks like one plant. I mean, the thickness of those bars is one.

MR. MATTHEWS: Right. One plant in the top five -- in less than five. Three of the plants, I believe, had already done inspections, and the other three were very nearly identical to other units that had already inspected or announced plans to inspect. So -- in that short bar.

CHAIRMAN FORD: And this is purely mirroring the fact that the only cracking you had seen had been at DC cook up to that point?

MR. MATTHEWS: At this point in time, the only cracking had been DC Cook.

CHAIRMAN FORD: And this country?

MR. MATTHEWS: In this country, correct,

and that was -- It was just a normalization point to try and rank the plants. Recently --

MR. MEDOFF: May I clarify that a little bit? That's only for --

CHAIRMAN FORD: Identify yourself, and come to a microphone.

MR. MEDOFF: My name is Jim Medoff. I was the lead reviewer for GL 97-01.

That's true in terms of axial stress corrosion cracking induced flaws, but there were some shallow crazed cracks found at Oconee unit 2.

MR. MATTHEWS: That's true. There were some very shallow cracks that were monitored through repeat inspections and were not growing.

MR. MEDOFF: So I just want to clarify that.

MR. MATTHEWS: Yes. But as far as a deep flaw that was growing through the wall, at that point in time Cook-2 was the only data that we had.

(Slide change)

MR. MATTHEWS: Recently, starting last fall, we found OD-initiated flaws. These flaws are initiated below the weld on the portion of the tube that sticks down below the weld. Either there or in the weld flaws have been found at Oconee-1, Oconee-3 in February, ANO-1 found one flaw, and then Oconee-2 also found some flaws. All of these are B&W units, B&W designed units.

(Slide change)

MR. MATTHEWS: Based on that -- and I'll cover this in a little more detail -- we decided we didn't really have a good handle on what the material and stress was doing. So we decided the simplest thing to do was assume everybody was very similar to Oconee, and rank them just based on time and temperature.

Now they don't all operate at the same head temperature, but what we did was we normalized them through the Arrhenius equation to 600 degrees Fahrenheit, and we ranked the plants. There's a lot of detail in the color here, but I'm not sure we need to get into all that, as to who had already done inspections, etcetera.

DR. WALLIS: I'm assuming that the only variable that matters is these effective full power years.

MR. MATTHEWS: Effective full power years is the surrogate we were using for how long the plant had operated, and then the temperature of the head.

DR. WALLIS: But if there were some effect of water temperature, which were not quite the same between plants, then this might change things quite a lot.

MR. MATTHEWS: It could. It could change it some anyway, but they all run with very similar boric acid, water concentration that goes down, the very high purity water at the end of the cycle. The water chemistry variable, agreed, is not in there. Assume everybody had similar situation to Oconee-3.

This histogram was put together based on preliminary information that we had at the time we put this together.

CHAIRMAN FORD: Just to make sure that I and, I'm sure, the others, understand this: What you have essentially said is that you've got a given plant, for instance.

MR. MATTHEWS: Yes, the worst one.

CHAIRMAN FORD: Which has got a certain number of real effective power years under its belt right now, and then you have modified those years, taking into account the differences in head temperature between that plant and Oconee, and the way you've changed it is by using Arrhenius -- well, an activation enthalpy of 55.

MR. MATTHEWS: In fact, all the plants,

even the Oconee units were normalized to 600 degrees. They run slightly above 600. So their numbers were all shifted slightly based on that. Six hundred was our base temperature that we were using, 600 Fahrenheit.

DR. KRESS: How did you know what activation energy to put in?

MR. MATTHEWS: We used the 50 kilocalories per mole for crack initiation, and that was the number. The NRC had asked us some sensitivity questions on that, and I've got some of that in here.

CHAIRMAN FORD: And that's based on the French -- No, I'm sorry, the United States data. Is that right?

MR. MATTHEWS: 50 kilocalories?

CHAIRMAN FORD: Is based on laboratory data?

MR. MATTHEWS: Yes.

CHAIRMAN FORD: American laboratory data?

MR. BAMFORD: We have a lot of experience with cracks in steam generator tubes, and that's kind of an amalgamation of the available world data, and we looked at the sensitivity of that value, as you will see in a slide coming up.

DR. WALLIS: What is the uncertainty in

this 50 kilocalorie per mole figure?

MR. MATTHEWS: We got a sensitivity study. I'm not sure we have an uncertainty on it. That's the number that we've been using. That's the number that's --

DR. WALLIS: Yes, but you are uncertain. It's something between 30 and 70 or something like that. That might make a big difference to your curves.

MR. MATTHEWS: Well, we ran the sensitivity study, and it doesn't shift the relative rank, because all the plants, even the Oconee units, move as you do that, and that's what we were doing was relatively ranking them.

CHAIRMAN FORD: I think it would be fair to say, would it not, that if you're looking at all the steam generator data plus what head penetration data you've got, 50 is a conservative upper limit. Is that correct?

If you look at the data then, it looks like a shotgun, but it's a reasonable upper limit. Is that a fair statement?

MR. MATTHEWS: Yes.

MR. ROSEN: Would you go back to the schematic for a minute?

(Slide change)

MR. MATTHEWS: We'll get to this again later.

MR. ROSEN: No, the schematic of the CRDM nozzle area.

MR. MATTHEWS: I should pull those out.

MR. ROSEN: Slide six. Take out your light pen, and trace for me what you mean by an outside diameter weld crack. Show me exactly where it initiates and what the leakage path is that you think --

MR. MATTHEWS: Cracks were initiating in this region here on the outside diameter of the tube, some of them.

MR. ROSEN: Close to the weld?

MR. MATTHEWS: Yes, most of them probably very close to the weld, propagating along the weld interface in an axial direction, penetrating both into the tube and, in some cases, into the weld material. And when it reaches this point right here, there's an only an interference fit, and then a gap above that, and that's where the leakage was occurring.

MR. ROSEN: How far from the weld, below the weld, was the furthest crack initiating?

MR. MATTHEWS: I believe they've had axial cracks that extended all the way to the end of the tube down here.

MR. ROSEN: So that's how many inches?

MR. MATTHEWS: Well, it depends on the penetration and the design, but the diameter here is four inches, and this is pretty much the scale for one of these penetrations out on the edge.

MR. ROSEN: So it could be six inches perhaps to the bottom?

MR. MATTHEWS: Between five to six inches, yes.

MR. ROSEN: Thank you.

CHAIRMAN FORD: It's a good point, Steve. So there's an axial crack going up that interface. Where does it go circumferential, at that point there?

MR. MATTHEWS: Right here?

CHAIRMAN FORD: Yes.

MR. MATTHEWS: Along the heat effective zone from that weld, that is where circ-cracks have been detected on three penetrations in the U.S.

CHAIRMAN FORD: And will you be discussing later on -- I'm sure you will be -- the extent of that circumferential cracking and the safety input?

MR. MATTHEWS: Yes, I'll get into a lot of detail on what was found at Oconee.

CHAIRMAN FORD: I'm sorry. This is so interesting, I'm jumping. Why should it go circumferential?

MR. MATTHEWS: The only reason it goes circumferential is if the axial stresses in that region are sufficient to support a crack that's in a circumferential direction.

CHAIRMAN FORD: And there's analysis to show that?

MR. MATTHEWS: Yes.

CHAIRMAN FORD: Okay.

MR. ROSEN: But at some point, clearly, it's penetrated the wall. Right?

MR. MATTHEWS: It has either penetrated the wall and bypassed the weld or it's gone through the weld to this triple point right here where you have the weld material, the head and the tube, and gotten above the weld into this annulus region above the weld. The flow path either through the crack to above it or, if the crack extends all the way to the ID of the tube, which a few of them did, you could have a flow path going this way.

DR. WALLIS: What are the stresses that induce these cracks?

MR. MATTHEWS: Most of the stresses are

probably residual stresses from the manufacturing process. These penetrations, in most cases, were not stress relieved with the head.

DR. WALLIS: So that could be a considerable variable between plants in the way in which the stresses were relieved and the manufacturing?

MR. MATTHEWS: The manufacturing processes were very similar for all the heads, but yes, there could be some variation.

MR. HUNT: I think the answer there is the stresses were not relieved after manufacture for any of them. The J-groove welds were prepared, and then the head was put into service, went through a hydro test in the interim, but there was no stress relief done to the J-groove welds. So it has all the welding residual stresses locked in.

MR. ROSEN: Have you seen any cracking initiate in the weld material itself?

MR. MATTHEWS: There was one crack at Oconee that it wasn't clear whether it initiated in the weld or in the tube. I believe, you know, it was in both. The initial discovery of the crack was by PT of the weld area, and that's where the crack showed up, the weld. Was that on the uphill side or downhill? Downhill side. They found a couple of little PT indications on the weld itself, and that was the initial indication, and as they ground out, they discovered the crack actually penetrated into the tube material, through the weld, to this annulus region. I have some pictures on what we saw when we go tin there.

DR. WALLIS: So these stresses that caused the cracks were residual from manufacturing. So if you took these things and put them in the same temperature environment, which was not in the reactor at all -- it was just in a bath -- you would expect the same kind of crack growth?

MR. MATTHEWS: With the same stresses, I would suspect.

DR. WALLIS: Well, if it's all residual stresses, then the fact that it's part of a reactor is irrelevant, isn't it?

MR. MATTHEWS: Yes.

DR. WALLIS: Is that your contention, that that is the case?

MR. MATTHEWS: Yes, I think so.

DR. WALLIS: That any kind of loads imposed by the fact that it's part of a reactor or that it's in this environment is irrelevant?

MR. MATTHEWS: Well, it's also subject to the operating pressure stresses.

DR. WALLIS: But that hasn't been mentioned yet. Does that play a role?

MR. MATTHEWS: They are not the driving stresses, I don't believe. I believe most of the driving stresses are the residual stresses from the manufacturing process.

MR. LEITCH: When comparing plants, why is it that time at temperature is the variable of interest rather than number of thermal cycles?

MR. MATTHEWS: I believe -- and somebody correct me if I'm wrong -- that the initiation of the cracking in alloy 600 tends to be more of a -- It's not a fatigue type of initiation. It's just a PWSCC stress corrosion cracking, and time at temperature is the driver there, and stresses in the material properties.

MR. BAMFORD: This is Warren Bamford again. To clarify that, the stresses that -- or the transient stresses that occur in the upper head region of an operating PWR are very mild, because the closure head region, that whole region is essentially a static area.

You get some water coming in from t-cold, and you get some water coming in from t-hot, and there's some mixing there, but the flow is very small there. So the transients that affect that region are very minor, and we actually looked at fatigue crack growth and other things that might go on that might affect this cracking when we first were looking at this back in the early Nineties.

The conclusion was that the overwhelming factor driving the cracks was residual stress, and everyone else, I think, worldwide has agreed with that. So I don't think there is any question about that.

CHAIRMAN FORD: So would you mind going back to the previous graph, because this, I think, is going to be -- You may very well be coming back to this graph.

MR. MATTHEWS: I'll save it out. I have another copy later in the presentation.

CHAIRMAN FORD: Just to be absolutely sure, the only variable -- You're going to be using this to make the argument, presumably, that this is the beginning -- the Oconee and the ANO experiences in this country. You're trying to rank all the other stations in comparison, and the only variable you're using for the top head is a temperature.

MR. MATTHEWS: Right.

CHAIRMAN FORD: Warren correctly pointed out just now that the main mechanical driver, of course, is the residual stress. Do we know -- and my guess is no -- how the residual stresses vary between these various plants? I don't know how you would do that.

MR. MATTHEWS: Well, they calculate them. We don't have any details, I don't believe, on the residual stresses.

CHAIRMAN FORD: So one of those plants that you're saying could be 50 years out might be, in fact, only two years out, because there's the upper bound of the actual residual stress profiles.

MR. MATTHEWS: Well, the manufacturing processes for all of these were very, very similar. So you would expect the residual stresses to be similar.

CHAIRMAN FORD: But you have no data to see what the distribution of residual stresses --

MR. MATTHEWS: We calculated those stresses, I guess, for various plants in the original model as a result of the weld residual stresses, the ovalization on the tube that occurs in the welding process, and the material properties, the yield strength of the tube, etcetera, and built a good model for calculating that.

CHAIRMAN FORD: I understand how a finite element might well look at those specific effects of those variables on the residual stress profile, but there's no way of looking at the plant at the righthand side of that graph and saying it should be there, and it shouldn't be over that side, because the residual stress aspects have changed. My point is it's an unknown variable.

MR. MATTHEWS: It's not a perfect model. There's no question about that.

CHAIRMAN FORD: I'm just trying to understand what the potential flaws in the model that you are using are.

MR. MATTHEWS: Right. That's one of the uncertainties, is the driving stresses, the material properties. What we've tried to do is say, well, what we know is Oconee-3 is the worst we've seen, and we are going to benchmark to there on the properties that we do understand.

DR. WALLIS: It's the worst you've seen, but you are guessing that there aren't worse ones out there somewhere, that they would have shown up if they had been worse. Is that the idea?

MR. MATTHEWS: Yes. We think so, and that's the position that we are taking, at least right now, but we've got uncertainty here, we're saying, and we're not just going to look at the next plant on the list. We're going to go out for a ways.

DR. WALLIS: I think you need to get into the matter of uncertainties of all of this, and it's not just one figure, really. It's a question of what happens if you go to some other limit of assumptions or look at the sensitivity. Are you going to give us sensitivity studies?

MR. MATTHEWS: Well, the only sensitivity study I know has been done right so far has been on the activation energy.

MR. BAMFORD: We were given some additional assurance when we set up this original time-temperature model and ranked all of the plants, and it turned out Oconee -- all three Oconee units were at the very top of the list.

So that gave us some confidence that the model made some sense relative to what we were seeing out there.

DR. WALLIS: The Arrhenius relationship, simply a curve fit to an exponential or something. Is that what it is?

MR. BAMFORD: Sure.

DR. WALLIS: And I'm not an expert on this field, but if I look at some data from something similar and I try to curve fit, do I get a lowest scatter around this curve or does the data from these sort of phenomena fit this curve very, very closely when you take a lot of lab data?

MR. BAMFORD: Well, you know, what we are doing is a deterministic model, and we are not trying to apply -- At least at this point, we are not applying any statistics to it, but the thing I wanted to point out was that we didn't go in with any bias in the way we set the model up.

DR. WALLIS: My sense is that this is a very crude representation of what happens?

MR. BAMFORD: Very simple, that's right.

DR. WALLIS: And expected to be very accurate?

MR. BAMFORD: Well, we tried it, because it was simple, and we were amazed at how the Oconee plants jumped right out at the top of the list, and that gave us some confidence to proceed, I think.

Now, obviously, we can improve on it, but I think it seems that we have some confidence in it based on experience, at least at this point.

MR. MATTHEWS: Need more data, though. Need more inspections. Now we've had some inspections this past spring, visual inspections that detected no leakage from other plants that are very close to Oconee in this time and temperature model.

(Slide change)

MR. MATTHEWS: Got a lot of information here on what actually happened at Oconee and A&O, and I'll walk through that and, if we get too detailed, just let me know.

Visual inspection of Oconee-1 head identified small amounts of boron that were accumulated around nozzle 21 and several of the thermocouple nozzles, and we have some pictures of some of this later on.

When they inspected the Oconee-3, they found several nozzles -- there's a list of them here -- that had boron accumulated at the base of the nozzle, indicating leakage.

Then when Oconee-2 came down, there was also leakage around four of their nozzles.

DR. WALLIS: Now this boron accumulation -- it's because the water comes out and evaporates and leaves behind the boron, and the water disappears?

MR. MATTHEWS: Yes. Well, what little bit of it there is vaporizes, and the --

DR. WALLIS: And the boron stays there?

MR. MATTHEWS: Yes.

DR. WALLIS: How much boron is there is a measure of how much water has leaked?

MR. MATTHEWS: Yes. And it depends also on what time in the life of the plant it leaks. Early in the life, there's a lot of boron in the water. late in life, there is almost no boron in the water. So how much boron accumulates depends on when it leaks, how much it leaks.

DR. WALLIS: When you say small amount, you mean less than an ounce or something?

MR. MATTHEWS: I'll show you some pictures. I think Oconee-1, they were estimating less than a cubic inch of boron crystals.

DR. WALLIS: This corresponds to how much water?

MR. MATTHEWS: We didn't do that calculation.

DR. WALLIS: Didn't do that calculation? It's a sort of --

MR. HUNT: It was about a gallon of water.

DR. WALLIS: It's how much?

MR. HUNT: About a gallon.

DR. WALLIS: About a gallon of water?

MR. HUNT: Yes.

DR. WALLIS: That's all that's leaked out of this thing?

MR. HUNT: Yes. It depends on the assumptions of the boron concentration.

DR. WALLIS: So it's a gallon of water that has leaked and left that boron behind? That's all?

MR. HUNT: Yes.

MR. MATTHEWS: Very little. PWSCC cracks are very, very tight.

CHAIRMAN FORD: Larry, we are peppering you with questions.

MR. MATTHEWS: Yes.

CHAIRMAN FORD: And we are about halfway through your time. You know what you've got in front of you.

MR. MATTHEWS: I've got a lot of detail on what happened at Oconee in A&O, and pictures and other inspections that have taken place in the industry in the submittals that we've made. I can walk through --

CHAIRMAN FORD: I think we're going to have to go very fast. I'm going to assume that most people have seen some of this information. The thing

I'm personally very interested in is your arguments on the safety point of view, the crack growth rate point of view, i.e., what's going to happen in the future. Those are the things I'm interested in. I don't know if any other members have got their own interests.

MR. MATTHEWS: I'll try and get on down to those.

(Slide change)

MR. MATTHEWS: Oconee here had modified their ports so they could -- their service structure.

(Slide change)

MR. MATTHEWS: You can see their thermocouple nozzles. Only two units have those, and they weren't used. I showed you where those were.

(Slide change)

MR. MATTHEWS: This is a picture of one of the leaking thermocouple nozzles. You can see just a little bit of boric acid or boric acid crystals that had deposited there as the water had leaked out and ran toward this. That's one of the mouse holes that is in all the B&W units.

(Slide change)

CHAIRMAN FORD: And we will be talking the

NDE techniques are being developed? Will we talk about that?

MR. MATTHEWS: Yes. They have 69 CRDMs. They are hotrolled and annealed B&W tubular products for Oconee. The nozzles are shrink fit into the vessel head and welded with that J-groove weld.

These are the summary of the leaks that were discovered on Oconee-1 and Oconee-3. The models that we had for the original OD initiated cracking, we are predicting it would occur predominantly on the outer rows, because that's where the residual stresses were the highest. These cracks were more scattered throughout the head.

CHAIRMAN FORD: And is that telling you the model needs to be tweaked a bit or what?

MR. MATTHEWS: Well, it's telling us that the model that we had for the ID initiated flaws isn't predicting what is happening here with the OD initiated flaws.

(Slide change)

MR. MATTHEWS: AT Oconee all eight of their small thermocouple nozzles had flaws. The CRDM, they only had one CRDM nozzle at Oconee, Nozzle 21, that had a flaw. That flaw was int he weld metal, predominantly axial and radial in orientation, and this is a photo of the boron or boric acid crystals that had accumulated around that nozzle.

(Slide change)

MR. MATTHEWS: When we got to Oconee-3, there were nine CRDM nozzles that were found leaking. These had numerous axial flaws, axially oriented flaws. OD initiated circ flaws that were relatively deep were found below the weld on four of the nozzles, and they discovered OD initiated circ flaws above the weld that were identified --

DR. WALLIS: For how long had they been leaking when they were found?

MR. MATTHEWS: We are not sure. This was the first indication that they had that they were leaking, but the heads, B&W heads, because of the flanged arrangements of CRDMs, have over the years had experience with boric acid accumulation. But this was the first indication that they had ben leaking.

I think everybody probably believes these cracks were there for more than this last cycle, but probably quite a bit --

DR. WALLIS: It's roughly for a cycle?

MR. MATTHEWS: I think it was much more than a cycle, but you know, that's my opinion.

MR. ROBINSON: We have kind of theorized, Larry, that it could be as much as -- This is Mike Robinson from Duke Power.

We have theorized ourselves that the cracks could have been there and the leaks could have been going on for a range of five to ten years, but we really haven't -- you know, don't have any way to really prove that. That's just an assumption on our part.

MR. MATTHEWS: One of the things Oconee had been doing, because of the ID initiation flaws, had been cleaning their head over the years to try and remove the accumulated boron so they could get a better look.

(Slide change)

MR. MATTHEWS: This is nozzle 56 on Oconee-3. This is one of the nozzles that developed a circ flaw above the weld after it had had an axial flaw go through-wall.

DR. WALLIS: Why is that different colors? Seems to be a river running down below. Does it tell you anything, what you see? It just tells you there's a leak?

MR. MATTHEWS: There is a leak. The white is the boric acid crystals, some corrosion of the carbon steel, alloy steel, whatever. It's mixed together.

DR. WALLIS: There is a stream of fluid running down below there?

MR. MATTHEWS: A little bit, but it doesn't make it to the service structure on this particular nozzle, or any of them, I don't think.

DR. UHRIG: Is that circumferential line there -- is that a crack?

MR. MATTHEWS: No, the circumferential line -- you'll see that on most of the penetrations -- is the upper end of the machine area where they machined them for the fit, for the interference fit.

DR. WALLIS: What is all that stuff that's higher there? Is that something running down from somewhere --

MR. MATTHEWS: That is probably -- I'm not sure they know, but I think they believe it's the fibrous material from some of the --

DR. WALLIS: It's not cracks. It must be something else.

MR. MATTHEWS: No. It's stuff that was left over from their cleaning operation.

DR. KRESS: What temperature does the head run at?

MR. MATTHEWS: This head runs 607, is it?

602, I'm sorry.

DR. KRESS: When the water comes out, it's almost immediately --

MR. MATTHEWS: Oh, it flashes, yes. As soon as the pressure drops low enough --

DR. WALLIS: That is why it is surprising it actually runs down very much.

MR. MATTHEWS: Maybe it recondenses and then runs.

(Slide change)

MR. MATTHEWS: This is nozzle 50. This is the other nozzle that had a circumferential flaw on unit 3. You can see some of the boron that's -- you know, little crystals scattered around from plant leaks, etcetera, but the leaks have typically been pretty obvious that you got something --

MR. ROSEN: And here again, all that white coloring is what?

MR. MATTHEWS: It's just a fine dusting of boric acid from crystals. As water has leaked from various sources, even from the flanges or -- The CRDM modules are bolted above these.

MR. ROSEN: Are we talking about the same thing? I'm talking about all of the white.

MR. FYFITCH: Yes, let me explain, Larry.

Let me tell you. This is Steve Fyfitch from Framatone.

In the B&W design, as Larry mentioned earlier, we have a flange on top of the CRDM nozzle. It connects the control arm drive to the nozzle, and those flanges typically leak. It's just a gasket and flange.

Over the years, we have done much better at coming up with better gaskets so that they leak less and less, but all of the heads in the B&W design have a coating of boric acid on the head from that leakage.

Over the years since the early Nineties, our plants have continued to clean that boric acid off, and what you are seeing there are residual boric acid crystals that have been washed away and have redeposited along the head there. So really, what we are only talking about in that center nozzle there, which is nozzle 50, right around the outside, the OD of the nozzle, is the leakage that you are seeing from the flaw that's on the inside. It's coming up and leaking out.

MR. ROSEN: Thank you.

MR. LEITCH: In some of the reading we had, there was quite a bit of discussion about the interference fit and the variability in the interference fit. But I kind of lost my way through that. Is there some -- In other words, the question is could we have crack welds down below that, because of a very heavy interference fit, it didn't appear as boron crystals?

In other words, is there some correlation that the ones that were obvious leakers had perhaps even a clearance fit, and there were some nozzles that --

MR. MATTHEWS: No, we have data on those particular nozzles, and no, they were interference fits, and we'll show you. They are interference fits by design at cold temperatures. Operating temperature and pressure, things change; and we got some stuff in here on that.

MR. LEITCH: So that is going to come later?

MR. MATTHEWS: Yes, that's one of the things that we've been concerned about and the NRC has been concerned about.

MR. LEITCH: Okay, thank you.

(Slide change)

MR. MATTHEWS: ANO, in the middle of all this, found one leaking nozzle. It was an axially oriented -- I mean, it was a flaw that had a circumferential part to it below the weld, and then it turned axial.

MR. BONACA: Could you go back into slide 23?

(Slide change)

MR. BONACA: Given that you have all this boric acid crystal residue over it, how can you detect leaks positively from visual inspections?

MR. MATTHEWS: That is one of the things that we have to do, is make sure that what we are looking at is adequate to find those kinds of leaks, that small amount of boron, and we are orienting visual inspectors and everybody as to what exactly they are looking for, in all of the plants.

The B&W plants are the ones with the flange. Not all the plants have that much boric acid accumulation, and I'll show you some pictures later on.

MR. BONACA: But the other question is: If this leakage is coming from the flange above, how come the nozzles have no trace of deposit on them?

MR. MATTHEWS: Oh, this leakage here has accumulated over the years.

MR. BONACA: Yes, but I guess it would

drip down through over the nozzles.

MR. MATTHEWS: Yes, come down through the insulation.

MR. FYFITCH: Let me address that again. In Oconee's case, you know, they have cleaned it up fairly well. This is a very clean head compared to some of the old BW heads. Yes, indeed, you do see leakage coming down the nozzles, but what typically happens is the flange, which is above the insulation, when it leaks, it leaks onto the insulation, and it would tend to come down and drip down through the insulation, and you get these crystals that deposit on the surface.

So you do get both cases.

MR. BONACA: All right. Okay.

(Slide change)

MR. MATTHEWS: ANO doesn't have those large access ports. So they put a video camera underneath their insulation through the mouse hold, and this is the one flaw that they had at ANO. The picture in the thing didn't come out, but the same picture. This picture is in the response to the NRC questions that we submitted a couple of weeks ago.

CHAIRMAN FORD: You skipped over a graph, and thank you for doing it in order to get moving.

But then the very first bullet on it says "No idea axially oriented flaws identified."

So how --

MR. MATTHEWS: There was no ID flaws at all. The only flaws they had at ANO -- I'm sorry, I didn't mean to interrupt. But the flaw that's on the OD below the weld and then propagates up along the heat affected zone.

CHAIRMAN FORD: I'm just trying to work out how you can have an OD circumferential crack without an axial crack. I thought the axial crack is a precursor.

MR. MATTHEWS: It was right in here, and it's circumferential. Then when it got here when it intersected the weld --

(Slide change)

MR. MATTHEWS: All right. Here is quite a bit of information that was -- Oconee did on their investigations. Before they did their repairs, they did visual on all the nozzles. They performed dye penetrant on the leaker. There was eddy current testing on the leakers and other nozzles, UT examination looking at both the axial and circumferential direction.

(Slide change)

MR. MATTHEWS: The visual inspections were bare head inspections. They do this every outage. The Oconee units have been cleaned well over the years to remove most of the old boron deposits.

CHAIRMAN FORD: So when you take the head off, you've got real access to these things, don't you?

MR. MATTHEWS: No. They only have access through like a 12-inch hole.

CHAIRMAN FORD: That's all?

MR. MATTHEWS: Yes, at Oconee. In some of the plants it's just through those little mouse holes that I showed you, the B&W, and the Westinghouse and CE plants, some of them have much less access than that.

MR. LEITCH: The visual inspections you referred to were with the head off under the head, or how?

MR. MATTHEWS: It was above the head, like what I showing you in the pictures.

MR. LEITCH: So, really, all you are looking for is boron crystals.

MR. MATTHEWS: Right. You're looking for evidence of leakage.

MR. LEITCH: So that would be -- How much leakage you get would be not only a factor of what was a crack but also the interference fit. Right? In other words, if they are very tight, you might not get any leakage evidence.

MR. MATTHEWS: That's definitely one of the concerns of the NRC. We believe that most of these, if not al of them, will leak. If the crack itself leaks, then the fluid will get on out to the top of the head.

DR. KRESS: What is the relative thermal expansion coefficients?

MR. MATTHEWS: There's a couple of numbers. In one of the code cases, the latest -- I mean, the latest version of the code, the thermal expansion coefficients are identical. In an earlier one, the -- and I'll get into that. In the earlier versions of the code, the thermal expansion would tighten the fit up, but the pressure dilation would open it up more than the thermal expansion tightens it up. We've got some information on that.

(Slide change)

MR. MATTHEWS: At Oconee, they also did UT exams looking in the axial and the circumferential direction of leaker penetrations as well as some other penetrations, expanding the scope, looking a little bit beyond that.

(Slide change)

MR. MATTHEWS: The next three are just some of the PT indications that were found on three of the nozzles. This is nozzle 11. You can see that it has a circumferential flaw and axial flaws coming out the bottom of it.

DR. WALLIS: Has anybody looked at what really happens? When you get flashing liquid leaking out through a crack, I would think it would flap way down in the crack, leave the boron behind, and all that will come out would be steam. It would be a long time later that you would actually get boron appearing out the top.

MR. MATTHEWS: The experience that we've seen on like a flange leak or other things, you don't have boric acid accumulated all along. Where you get it is out at the -- when it gets to the atmosphere.

DR. WALLIS: But the pressure drop is inside. That's where the flashing occurs, and the steam would b released inside for a long time.

MR. MATTHEWS: I understand.

DR. KRESS: It depends on the pressure. When you flash steam at a high pressure, which would have then, I suspect, near the front of the crack, it takes the boron liquid into the steam. But if you flash it at low pressure, it leaves it behind. So it could be carried out, actually, with some of the steam.

DR. WALLIS: Blow it out with the steam, yes.

DR. BONACA: I have one question. Before we talked about visual is the first step in the inspection, and it has to be -- Then after that, you do dye penetrant and eddy current and so on.

MR. MATTHEWS: That's what happened historically.

DR. BONACA: Yes. I'm just pursuing the question. Again, you have boron crystals all over the head. How can you be sure that you have identified all those that leak?

MR. MATTHEWS: Well, you have to do a very careful look. There is no question about that. And not all of the heads -- you know, and I got a picture of a -- several pictures of some of the others I'll show you. They are not in your packs, but they were in our submittal. Not all the heads are that -- got that much boron laying on them.

(Slide change)

MR. MATTHEWS: That was another nozzle,

and here was another nozzle that developed above the weld after this. This flaw had grown all the way through and leaked into the annulus region.

(Slide change)

MR. MATTHEWS: AT Oconee-3 they had 48 indications in the nine leaking nozzles. Thirty-nine of them were axial and located beneath the weld at the uphill and downhill side, and 16 of the indications actually were all the way through the wall. All of those were axial, and they occurred on six of the nine nozzles.

They had two nozzles that had confirmed circ flaws. Nozzle 56, the circ flaw was above the weld, and it was through the wall. In Nozzle 50 it was a significant extent around the weld, but it was only through the weld on the ID for a couple of pinholes on the PT. The inspection and the results indicate that those came from the outside after the penetration had been penetrated.

DR. WALLIS: What about all the nozzles that didn't leak?

MR. MATTHEWS: They did extent of conditions on examinations with eddy current and UT, looking for anything else on other nozzles. They didn't do 100 percent --

DR. WALLIS: Doesn't this give you some idea of the scatter in the fit to this Arrhenius equation? If they have all had the same history and some of them leaked and some of them had lots of cracks and some didn't have cracks, it tells you something about your ability to predict.

MR. MATTHEWS: It was almost like two populations at Oconee. It really was. What we are doing is saying everybody is as bad as their worst.

DR. WALLIS: That's a bit disconcerting, though, because it means that some were considerably different from others.

DR. MATTHEWS: Yes.

DR. WALLIS: And that just sort of belies some of the predictability of things.

DR. KRESS: That could be due to cracking initiation. You may already have cracks in some of them, small cracks, and not in the others. If you don't have any in them, it will take a while to initiate the crack. What we're really looking at is crack growth, I think.

CHAIRMAN FORD: Larry, Oconee was inspected somewhere around the end of the year 2000 and 2001. What was the previous inspection?

MR. MATTHEWS: They had done an inspection one cycle before, 18 months, I guess.

CHAIRMAN FORD: So all indications that you're seeing there occurred -- I'm assuming that there's no indications in the previous inspection.

MR. MATTHEWS: They say they were discovered. Okay?

CHAIRMAN FORD: Okay. How do you tell a new one from an old one?

MR. MATTHEWS: I'm not sure you can. You could do some analysis on the boron. It might tell you how old the boron has been -- you know, some radiochemistry on the deposits that could tell you how old the boron is, but I'm not sure that's very accurate at this point.

MR. ROBINSON: This is Mike Robinson again from Duke Power. We did do some of the radiochemistry on the sample we found on Oconee-1. As you would imagine, with some of the old boron there as well as some fresh boron, we had a range of age from the samples that we did take.

So we could see new signs where leakage had occurred within the last cycle. We also had evidence where there was boron again mixed with the samples that we took that were somewhat contaminated but also indicated a much longer period of being on the head.

As for Oconee, I guess we're somewhat fortunate. The individual who does these inspections for us -- We do these inspections looking at the top of the head within two days of the unit coming offline. So before we take the head off and put it on the stand, the engineer takes a look at our head.

Again, we are fortunate. The individual who does these inspections for us has done those for about the last 15 years. So we have an experienced dye ed. and, as much as we've cleaned the heads, who has a pretty good understanding of what's there.

When we found the indication on Oconee-1, we went through this series of inspections that Larry is talking about here. We did the looks at the ID, because again once we saw the boron, we were suspicious as to what was there.

We thought it was, again, typical PWSCC. It was typical ID initiated cracking. So all of our initial investigations focused on interrogating the ID surface, trying to find a crack.

Much to our surprise, when we got our NDE back on the leaking CRDM nozzle, there were no ID indications. At that point, we went to the OD and started looking there and didn't find anything. We ultimately found some cracks in the weld itself.

Oconee-1 happened. That's when we found the leaks with the thermocouple as well as the CRDM nozzle 21. Before Oconee-1 came down, we had the Oconee-3 refueling outage, and at that point we didn't observe anything in Oconee-3, but subsequent to Oconee-1 we had to bring Oconee-3 down for a maintenance outage to repair a leaking pressurizer valve.

Our sensitization to what we had found on Oconee-1 sharpened our eye when we did the inspection on Oconee-3, and I think that's why we were able to pick up some of the leakage on Oconee-3. Our heads on Oconee, we feel like, are in pretty good shape.

Oconee-3 was probably the least clean of the heads we have there. So in spite of the fact that it was not as clean as the other two heads, we were able to see again some of the small leakage.

MR. ROSEN: When you talk about circumferential cracking, you don't talk about the extent of it. Is it all the way around?

MR. MATTHEWS: No, it's not. The two flaws on Oconee-3, the crack was approximately 165 degrees around from the uphill side on the OD of the penetration.

MR. ROSEN; Halfway around?

MR. MATTHEWS: Yes, almost halfway around. And there's plenty of structural margin there to preclude rot ejection.

MR. ROSEN: That was the biggest one you've ever found, halfway around or almost halfway around?

MR. MATTHEWS: Yes. That's the biggest flaw we've ever found, was one of the two nozzles on Oconee-3, circumferential.

DR. WALLIS: You talk about axial and circumferential, but aren't there some other angles?

MR. MATTHEWS: If it's not pretty much axial, we tend to call it circumferential.

DR. WALLIS: Anything that deviates from axial is circumferential?

MR. MATTHEWS: It certainly has a circumferential component.

MR. ROBINSON: I think the line is 45 degrees, Larry. Anything that's off by more than 45 degrees, we call a circ crack.

DR. WALLIS: Oh, but an ax crack, which is at 44 degrees, eventually goes around.

MR. MATTHEWS: If it's got enough room, yes.

DR. WALLIS: It spirals.

MR. MATTHEWS: Yes. It wouldn't eject if it did that, though.

DR. WALLIS: It would screw its way out, wouldn't it?

MR. MATTHEWS: I guess it could.

CHAIRMAN FORD: Larry, if I could --

MR. MATTHEWS: We would find that.

CHAIRMAN FORD: In view of time, I think the remaining ones you've got are just essentially telling us again you've got cracks.

MR. MATTHEWS: Yes, and the metallurgy.

CHAIRMAN FORD: Could we move on to the safety assessment, Item 48?

MR. MATTHEWS: Forty-eight? Is that where I need to go?

CHAIRMAN FORD: I think the other one is just to do with organization, which I'm sure is important, but I'm looking at the time.

DR. WALLIS: I think the key question is how do you reach the conclusion that everything is okay?

CHAIRMAN FORD: I think so far what they've done is they've told us there are cracks. Now what I'm interested in is to know what is their assessment.

MR. MATTHEWS: Yes, and their PWSCC.

(Slide change)

MR. MATTHEWS: We submitted an interim safety assessment to the NRC in May, and with the histogram we've already talked about what developed as part of that, to rank the plants and sorted the plants into various bins.

We recommended that the plants that were less than ten years from being the equivalent to Oconee-3 perform visual examinations at their next opportunity. Those visual examinations need to be keyed to the results from Oconee-1 and Oconee ANA and O units, because up until that time I think everybody expected a greater amount of leakage.

(Slide change)

MR. MATTHEWS: There's the histogram again.

(Slide change)

MR. MATTHEWS: Our bases for believing that there is no significant near-term impact on plant safety is that the three Oconee units and the ANO-1 unit are all among the lead units in the U.S., based on this time at temperature.

Careful visual examination is able to

detect these leaks. Structural integrity evaluation showed that the nozzles and the welds were well within the required margins. Leakage should be detectable at other plants, and we'll get into that a little bit.

Several other lead units with long operating times and high temperatures have already inspected above the heads, looking for leakage, and have not had any significant findings.

Finally, from a safety standpoint, the CRDM nozzle ejection is an analyzed event in the plant FSARs, and the operators are well trained on symptom based emergency operating procedures to know how to respond to this.

DR. WALLIS: What is missing here is the time to ejection. Suppose there's an undetected crack. Is it ten years before it grows to the point where you worry about it or is it one cycle?

MR. MATTHEWS: We believe it's years and years.

DR. WALLIS: Can you actually show that?

MR. MATTHEWS: I think we can, but it depends, like you say, on the crack growth rate, and we have to get into what is the crack growth rate.

(Slide change)

MR. MATTHEWS: The NRC has identified

several questions to us based on our submittal.

DR. WALLIS: Isn't that really key, the crack growth rate?

MR. MATTHEWS: Yes. I think it's one of the key things, and when we use what we believe are realistic crack growth rates, we calculate that there's years of margin, even at Oconee-3 before they would have reached an ejection situation, even with a 165 degree flaw. What?

MR. FYFITCH: There is an overhead, Larry, coming up.

MR. MATTHEWS: Yes, we'll have that a little bit later on.

MR. LEITCH: I have a question about Number 50, just back one, the previous one.

(Slide change)

MR. LEITCH: Several other plants with long lead operating times and high temperatures already performed inspections from above. That would be a visual inspection?

MR. MATTHEWS: Right.

MR. LEITCH; Now suppose they found nothing as a result of that visual inspection. Would that have been the end of it or -- In other words, are they all above and below?

MR. MATTHEWS: No. The below was referring to previous volume -- or ID initiated eddy current examinations. Nobody has -- Since Oconee-1, nobody has done any significant examinations below the head. They have all been above.

MR. LEITCH; So these plants that might be in the family with problems, if you will, they looked -- since Oconee, they looked above the head, saw nothing, and that was -- That's all they have done to this point?

MR. MATTHEWS: To this point, that's true.

MR. LEITCH: Well, it says from above and below the head.

MR. MATTHEWS: Some of the highly ranked plants had already done inspections in earlier years below the head. Ginna, for instance, and one of the Millstone units had done inspections from below the head with the robotic equipment, and they didn't detect anything significant.

The only significant flaw that had been detected to date was the Cook-2 flaw in the U.S.

MR. LEITCH: So that statement then -- This is pre-Oconee inspections?

MR. MATTHEWS: Yes. The below-the-heads were pre-Oconee.

CHAIRMAN FORD: Before you come off that, some of the questions associated with those bullets are addressed by the NRC questions.

MR. MATTHEWS: Yes.

CHAIRMAN FORD: Two are not -- or one is not. Jack, the structural integrity evaluations -- is that okay, as far as you are concerned? It is more an analytical thing. Should we be worrying about this at this stage? Should we be following up in questions? I'm trying to cut down the time.

MR. STROSNIDER: This is Jack Strosnider, Director of Division of Engineering.

When you talk about the -- Let me make sure I understand your question. When you talk about the structural integrity evaluations, basically using a limit load type analysis? You are asking if that is acceptable to the staff?

The answer to that is yes. We think that is an appropriate method, and we haven't identified any issues with that.

I need to point out, it doesn't include crack growth rate analysis. I'm just talking about assessing a remaining ligament and its capacity.

CHAIRMAN FORD: We are about to come onto that very interesting aspect, I think, in a minute.

The CRDM nozzle ejection analyzed event -- and I'm sure in my ignorance at this point. What happens if a whole lot of adjacent nozzles are ejected?

MR. MATTHEWS: Well, then you have a larger LOCA.

CHAIRMAN FORD: And is that a part of your safety case?

MR. MATTHEWS: It's not. Multiple rod ejections from a reactivity standpoint is not analyzed. Lots of coolant accidents much bigger than a 2 1/2 inch hole are analyzed, and the operators are trained on how to respond. No matter what size the LOCA, they go to symptom based --

CHAIRMAN FORD: Multiple rod ejections are not analyzed? The consequences are so undesirable?

MR. MATTHEWS: Not from a reactivity standpoint. The single rod ejection was selected as a bounding reactivity insertion event for analysis in the design specs.

CHAIRMAN FORD: And yet you were showing pictures earlier on of a lot of cluster of OD cracks, circumferential cracks.

MR. MATTHEWS: Yes. The probability that you are going to have more than one of these go at one time, it's got to quite, quite low. The probability to have one go is pretty low, we believe.

MR. HUNT: This is Steve Hunt. A clarification on that picture, the one that showed the cluster of nozzles and cracks: Those were axial cracks. There were only two in the head that had circumferential cracks that were measurable.

CHAIRMAN FORD: Okay. I'm trying to cut down so that we've got plenty of time to talk about stress growth in cracking.

DR. WALLIS: We don't have to stop at 2:30, do we?

CHAIRMAN FORD: No, but -- Well, I want to give the NRR --

(Slide change)

MR. MATTHEWS: The NRC asked us several questions in May relative to leak detection, our time and temperature histogram, the growth rate of circ cracks, and some loose parts in risk assessment. Then later on they asked us questions concerning show us what it looks like when you have done these visuals at other units besides Oconee, and questions relative to the inspection capability of the industry, besides just the visual.

(Slide change)

MR. MATTHEWS: The interim safety assessment was prepared to demonstrate the safety of the plants. We currently have efforts going on associated with putting together the final safety assessment.

Visual inspections of the reactor vessel top head surfaces were recommended and are being recommended for the plants that are coming down in the fall. Research into improved inspection and repair technology is going on.

We are working on putting together a good risk assessment, and the results of all this will be factored into our final safety assessment.

(Slide change)

MR. MATTHEWS: In the area of leak detection, the Oconee and ANO plants detected the leakage, but the question is there's some plants out there that have greater, by design, interference fits than the B&W design.

Leakage should be detectable at most other penetrations, given similar cracks, we believe. On the other nozzles that were inspected at Oconee that did not show the leakage outside, there was no evidence that there was any kind of a through-wall indication on any of those.

The interference fits at all the other plants are only slightly larger than the ones at Oconee and ANO, and further experience has shown that it's difficult to prevent leakage of 2250 pound water without some kind of roll or hydraulic or explosive expansion or use of a sealant.

DR. WALLIS: I would think the boron would be a sealant.

MR. MATTHEWS: The boron tends to -- Even on very tight cracks or very tight leaks at flanges, etcetera, the boron tends to make it all the way to the outside, and that's where -- and still leaks.

DR. WALLIS: It oozes out then, like toothpaste?

MR. MATTHEWS: Yes, I would think. I'm not sure. It's kind of like crystals, but yes.

MR. LEITCH: So the conclusion then is that the boron is a reliable telltale?

MR. MATTHEWS: Yes.

MR. LEITCH: And that's true for all -- regardless of PWSCC.

MR. MATTHEWS: That's how they discovered the Summer crack was boron. Numerous piping penetrations with alloy 600 similar designed J-groove welds have been discovered through boric acid crystals on the outside from where they have leaked. Feeder sleeves on pressurizers -- the boric acid comes out, and it's visible.

MR. LEITCH: But even with a very tight interference fit, the boron will still find its way out and be a reliable indication of a crack?

MR. MATTHEWS: We believe it will.

MR. HUNT: There is one bit of supporting evidence for that, and that was some pressurizer instrument nozzles at EDF, which were actually roll expanded into the shell, and they cracked inboard of the roll expansion, and they still leaked past the roll expansion.

DR. WALLIS: Is it true that experiments with leakage of borated water at these pressures through small cracks has only been performed on the heads of operating reactors?

MR. MATTHEWS: I would say it's probably been performed at -- Oh, with interference fit?

DR. WALLIS: No one has actually done lab experiments with pressure -- high pressure borated water leaking out through a tight fit?

MR. MATTHEWS: Not to date, no. I don't think we have.

DR. WALLIS: It seems like a very simple

thing to do.

MR. MATTHEWS: We don't have those experiments done yet.

DR. KRESS: Make a good Master's thesis.

(Slide change)

MR. MATTHEWS: On the leaks that occurred at Oconee and ANO, they actually had the data from the manufacturing for what the interference fits were, what was the OD of the machine nozzle, what was the ID of the holes.

One of the nozzles had a gap, but the rest of the nozzles had at least one end of the nozzle -- either the upper end or the lower end was an interference fit, and three of them had interference fits manufactured as tight as 1.4 mils interference, and they still leaked.

(Slide change)

MR. MATTHEWS: If you look at the effect of the operating conditions on the fit, the differential thermal expansion is only a small effect. If you look at the older version of the code and use those values, it increases the initial interference fit by less than 1.4 mils. But the change in fit under operating conditions is primarily due to the pressure dilation of the vessel head.

For that example, the hole would expand 4 mils, and the nozzle itself would expand under the pressure of .48 mils for a net decrease in the interference fit or increase in the gap of 3.5 mils. If you do have thermal expansion differential, it reduces that by whatever the differential in thermal expansion is. But the gap -- or the interference fit tends to get much less as you take the plant to operating conditions.

(Slide change)

MR. MATTHEWS: Finite element analysis has been done to show that the outer row of the CRDM nozzles displace laterally and become slightly ovalized in the vessel as the clearance -- if any clearance opens up under operating conditions. That displacement and ovalization reduces the leak path at some locations and tightens it at others around the circumference of the nozzle and has a tendency to create a spiral flow path around the nozzle, if those were to develop a leak.

There is also an effect, although it is pretty small, from the flange tensioning in rotation. That tends to increase the ovality and open up that spiral leakage path.

(Slide change)

MR. MATTHEWS: In the spring of 2001, after Oconee had discovered their leaks and the industry was sensitized to what the situation is and how small the boronic acid deposits are, Robinson 2, Salem 1, Farley 2 and Prairie Island 1 all did some form of complete vessel head inspections above the head, and McGuire 1 and San Onofre 3 did partial of some number of their penetrations.

These heads were reasonably free of the masking boric acid deposits, and none of these found any evidence of leakage.

(Slide change)

MR. LEITCH: I assume you can get a good look at these. In other words, some manufacturers, it's more difficult to look at than others.

MR. MATTHEWS: Yes. Here's an example. This is not in the handout, but this is what that shroud looks like. All the penetrations are inside there. It's kind of tough, but there's doors so you can open the doors, but even on many of the plants, if you open the doors, this is what you see.

You see the metal insulation and the penetration where it actually goes in the head is below these insulation panels. So it's pretty difficult on some of the plants to do.

This one is fairly easy to get to. Some of the other plants, the insulation actually hugs the head. It's riveted together. It's very difficult to get to or it is even calcite blocks that are cemented on. So some of them have a difficult time, but some of them don't.

This is the inspection that was done at Salem and what they were able to do. The upper head packages are different on a lot of plants, a lot of different designs. But what they were able to do was to lift the shroud and remove these vertical panels and the lower horizontal panels, and they get a very good look at the penetrations.

You can see, there's not a lot of junk laying around on their head at Salem.

MR. LEITCH; But on these plants where they did a visual inspection, regardless of the difficulty of doing it, it did turn out that they had a valid visual inspection?

MR. MATTHEWS: We believe those were pretty valid inspections, yes, especially -- yes, all of them.

(Slide change)

MR. MATTHEWS: This was the inspection that happened at Robinson. Somewhere back in time they had painted their heads. So there's a lot of paint still there. You can even see it swathed up on some of the penetrations, but they had a clear look.

Now the reason they got into it, they are one of the very highly ranked plants, but what they did was they had a -- I believe it was a con seal leak. So they had to go in and do some cleaning in some areas. While they were there, they decided to take all their insulation off, and they damaged it doing it, and they couldn't put it back, and they had to change their design and put a different kind of insulation back in there. But they had that kind of mirror insulation and destroyed it.

Prairie Island has some different package, and they can get in and get a good look at the penetrations at Prairie Island, and they do that routinely. But they are kind of unique.

(Slide change)

MR. MATTHEWS: This was the inspection that was done at Farley. It's kind of hard to see. A video tape is much more -- better to tell what's going on. But this is the penetration, and this is the actual interface with the head, and we were able to get the video probe up to all the penetrations and get a pretty good look.

There were a couple that had some insulation that we couldn't quite get 360 around, but those were the kinds of inspections that have been done.

McGuire and SONGS are listed as partial there. They are partial, because you couldn't -- the others could not be accessed. I believe McGuire did remove some panel to look at some of their outer row penetrations, and San Onofre insulation package allows them pretty easy access to the outer row or two of penetrations, but the rest of them are up under some insulation. It's difficult to get to.

CHAIRMAN FORD: Larry, what I plan on doing is that we will call a break at 10:15. And so we do not cut short much of the discussion -- I think you are about to go into the histogram stuff right now?

MR. MATTHEWS: Yes.

CHAIRMAN FORD: Since that is the basis of your current prediction methodology, let's take a quarter of an hour discussing that, take a break, and then we will discuss the crack growth rate stuff.

Ms. Weston reminds me, we've got some time this afternoon. So we might use that time that was going to be for discussion for the NRR presentation.

(Slide change)

MR. MATTHEWS: I knew we had too much.

CHAIRMAN FORD: That's okay.

MR. MATTHEWS: The time and temperature histogram or model or whatever we want to call it groups the plants according to the time -- and we are using effective full power years as a indication that the plant is at temperature -- required for each unit to reach the equivalent effective time at temperature as Oconee 3 at the time that the above-the-weld sort of cracks were discovered in February 2001.

So we took their numbers, normalized theirs to 600 degrees, took everybody else's numbers, normalized it to 600 degrees, took that difference in time then and converted the time back to whatever their operating head temperature is to figure out how much time in effective full power years they have until the time that they would be equivalent to Oconee-3, and we used that industry standard 50 kcal/mole for that temperature adjustment.

DR. WALLIS: So this is an entirely theoretical curve at this point?

MR. MATTHEWS: Yes.

MR. ROSEN: It's more of an empirical.

DR. WALLIS: It's entirely theoretical.

There is no data yet.

MR. MATTHEWS: Except for Oconee-1, 2, 3 and ANO.

DR. BONACA: But it assumes that Oconee is the first plant that has experienced leakage, and we really don't know.

MR. MATTHEWS: One of the things that was alluded to earlier was the --

DR. WALLIS: It is the extrapolation of orders of magnitude.

MR. MATTHEWS: Okay. That's all we got.

CHAIRMAN FORD: We talked earlier on about the effect of residual stress profiles. I know Warren has got this capability. Can you not also just modify this to take into account a supposed range of residual stress profiles and modify this further?

I'm just concerned that temperature is the only variable in this whole thing.

MR. BAMFORD: Let me try to answer that. This is Warren Bamford from Westinghouse.

The reason that we've gone to this model is purely pragmatic. We found that the previous model had in it materials variability. It had in it stress variability, because we know that as you go further and further out toward the edge of the head, the stress -- the residual stresses are a function of the angle of intersection of the tube in the head.

So on the outer edges, stresses are typically higher. All right? When we found out that there wasn't any pattern to the cracking that was showing up here, the idea that the stresses were the only driver behind this seemed to be no longer a good conclusion.

So in the time that we had, we decided to develop a simple model to see what would happen. We developed -- We dropped the stress effect. We dropped the material effect. All right? So we just -- We cut the model down to its very basics, just time and temperature.

When we looked at what came out, the Oconee plants came out right at the top of the model when we just simply ranked them. We weren't comparing to anything. We just ranked them. The Oconee plants all came out right at the top.

So that gave us some confidence that maybe this is a good way to rank things. Then we started ranking them to -- ranked the other plants relative to Oconee, because we really had put a lot of sophistication into some previous models, and we found out that what was happening at the Oconee plants and at ANO didn't seem to correspond to the level of sophistication.

So we had gotten more sophisticated than we had any right to be, I think. So we tried to back it down. But your question about the residual stresses, I think, is -- There is a brief discussion as well.

Residual stress calculations were done with sophisticated elastic plastic finite element models by at least five different outfits that I'm aware of. The results were very, very similar from all the different models.

That led us to the conclusion that there really isn't that much variability in the residual stresses. The only difference is the angle of intersection between the tube and the head, because the welds are made at an angle.

In fact, there's such an amount of deformation that it causes the tubes to become oval when they stick down inside the head. They actually are ovalized, and they are set in that position. So there is a lot of residual stress there.

The models that have been done by five independent organizations all gave essentially the same kind of results. Now the other thing you need to keep in mind with residual stresses: You don't get much higher than yield level residual stresses.

So the variability here is not huge, and as soon as you go above the weld region in these tubs, the residual stresses drop off very quickly.

So I don't think there is that much variability in the different residual stresses.

CHAIRMAN FORD: The reason I would debate that is your residual stress model, the model itself, not the data -- the model itself is reproducible between five laboratories, whatever.

MR. BAMFORD: Right. Now we might all be wrong, okay? But there's a lot of consistency there.

CHAIRMAN FORD: Two questions I would like to ask. One is that model that says it should be all around the circumference of the head, and it's not. Therefore, the model may be correct, but the data is giving you something else, because of whatever it might be.

MR. BAMFORD: That's right.

CHAIRMAN FORD: And so that's a variable that is not taken into account.

MR. BAMFORD: There is clearly more to the story than we are able to account for at the present time, and we are working on that. But we also have to deal with the plants that are out there that have to operate in a safe condition.

So where we are right now is taking our best shot with the information we have at hand.

MR. FYFITCH: Let me add one more thing. Steve Fyfitch from Framatone again. However, with the B&W design, though, the shape of the head is much flatter than most of the Westinghouse units. So when you calculate the residual stresses, the differences from the center nozzle, which has a uniform weld around it, versus the nozzles that are on the outer periphery do not change that drastic compared to when you calculate it for a Westinghouse head.

So those residual stresses are pretty much even for the B&W plants.

CHAIRMAN FORD: Larry, I've got a request. Are you going to be giving the presentation tomorrow to the full ACRS Committee tomorrow?

MR. MATTHEWS: Wasn't planning on it.

CHAIRMAN FORD: Yes?

MR. MATTHEWS: No. I wasn't planning on it. Did they say yes?

CHAIRMAN FORD: I don't know.

MR. MATTHEWS: News to me, if I am.

CHAIRMAN FORD: Well, there is going to be a presentation from someone tomorrow. I thought it was going to be you.

MR. MATTHEWS: I thought it was going to be you.

CHAIRMAN FORD: My request is that, you know, a lot is riding on this prediction model, this histogram, and you are saying the Oconee data. Can we see some data tomorrow to show that?

MR. MATTHEWS: We have a little bit here.

CHAIRMAN FORD: You've got some data with Oconee points up at the top and everybody else below?

MR. MATTHEWS: Yes.

CHAIRMAN FORD: Okay, good.

MR. MATTHEWS: And skip the 40 kcal/mole?

CHAIRMAN FORD: Yes.

MR. MATTHEWS: That would just move the histogram around slightly.

(Slide change)

MR. MATTHEWS: The ten-year period that we selected for inspection recommending that the people inspect was to account for all these uncertainties. Is it enough? I don't know. We thought it was enough for an initial crack this fall. It encompasses 25 of the 69 units in the U.S.

DR. WALLIS: What does ten-year period

mean?

MR. MATTHEWS: We were recommending that everybody who was less than ten years away from being equivalent to Oconee do an inspection this fall -- that's got an outage this fall.

DR. WALLIS: That's an engineering judgment?

MR. MATTHEWS: Yes, it's just an engineering judgment.

MR. HUNT: This is Steve Hunt. To put that in perspective, the predicted time for Oconee is approximately 20 years. So we are going back to plants with half the time at temperature as Oconee.

MR. MATTHEWS: Right. And all but two of those top 25 units will have an outage by the spring of '02 in which they can take a look at their heads, and we would reassess that after we get any data from the fall outages.

(Slide change)

MR. MATTHEWS: This was a different way of looking at the histogram that actually has numbers on it. Some of these numbers have changed. This is what we submitted. Plants have taken another look at what their real head temperature is instead of some super-bounding, conservative number they put in there.

If you look at this -- and you have a black and white copy, but the top three units right here, this is time for the plant to be equivalent to Oconee-3, and this is just where the unit stacks up in the rack.

This is Oconee-3, and the other two units here are Oconee-1 and 2, and those have all done inspections.

This is ANO, but after some reassessment -- or maybe this is ANO. This is one of the other plants that did an inspection this spring. This one did one, and this one did one. All those plants did visual inspections, full visual inspections, of their heads this spring.

CHAIRMAN FORD: But that is not your data -- that's not the proof?

MR. MATTHEWS: No. This is just how they wrapped up and saying we are going to get to them fairly quickly by looking at, you know, 25 units here before ten years. All of those units except for two of them would have outages before next spring.

DR. WALLIS: So if you could detect cracks in one that's out to, say, EFPY of 50, that would be a big surprise.

MR. MATTHEWS: That would be a big

surprise.

DR. WALLIS: That would tell you that your theory wasn't very good.

MR. MATTHEWS: It sure would. Here is another variable we don't know. All of the red squares here have outages scheduled in the fall, and we have recommended that all of them below ten years do a visual inspection of their heads this year.

MR. LEITCH; Is it possible to say what made Oconee the outlier? Was it time or temperature? In other words, they operate at a higher temperature?

MR. MATTHEWS: They are an old plant. They run at a fairly or quite high head temperature, and they have had very good runs on those units.

MR. LEITCH: So it's really kind of a combination of the two. It's not just one that predominates. They are both --

MR. MATTHEWS: Yes. The B&W units typically run at some of the highest head temperatures of any of the units. These plants out here -- we call them t-cold plants. They bypass an awful lot of the cold leg flow back to the head and keep the head pretty close, in some cases, to the cold leg temperature. So they are operating down around 560, 570 degrees with lots of temperature margin to the 602 that the Oconee units were running at.

Most of these units are Westinghouse and CE units. Most of them are in the -- below 600, but above 585 or so, up closer to 590 to 600, most of these, and the main variables between them is the -- Well, the only variable on this chart is the time and the temperature and normalizing it to 600 degrees Fahrenheit.

DR. UHRIG: Why is there a large gap in there?

MR. MATTHEWS: This big gap is -- This is probably the oldest cold head plant, and this is one of the newest hot leg plants.

DR. UHRIG: Difference in hot and cold is 15 degrees?

MR. MATTHEWS: No, it's significantly more than that. I don't have the exact number, but these plants here run in the 590 to 600 range.

MR. HUNT: It's the difference between around 600 for a hot head and 550-555 for cold leg. So it's about 45 degrees.

MR. MATTHEWS: And this cracking in the model tends to take off at 50 calories per mole, really takes off around 600.

DR. WALLIS: And because it is an

exponential relationship, 50 degrees makes a big difference.

MR. MATTHEWS: Yes, even the -Q over RT.

DR. UHRIG: I didn't realize it was 50 degrees here.

MR. MATTHEWS: Yes.

(Slide change)

MR. MATTHEWS: This is the same data, just blown up for the first ten years. Some of these plants have said they have gone back and looked. What we used when we initially put the histogram together was the temperatures that were in the 97-01 submittals. Some of the plants had just made awfully conservative estimates at that point in time.

DR. WALLIS: It means you expect cracks in one year?

MR. MATTHEWS: Yes. Well, no. You expect to be at the equivalent time and temperature as Oconee-3 in one year. I'm not going to say they are going to crack.

If you had exactly the same properties and stresses and material and everything else that Oconee-3 had, yeah, I guess you could say it would be expected.

DR. WALLIS: You guys are running a very

interesting experiment.

MR. MATTHEWS: Expensive, too. It's expensive to get the data out of it, too. But that's our histogram, and that's the basis, and our ten-year margin there was to try and cover some of these uncertainties. That's half the life of Oconee, as far as time at temperature, and we are saying everybody who is that close ought to be taking a look.

DR. WALLIS: So nothing you've said so far tells us why these plants are safe. That's what we are going to do with the crack growth argument, is it?

MR. MATTHEWS: Well, we believe Oconee was safe. They had plenty of margin to rod ejection at Oconee.

DR. WALLIS: Well, that comes because of crack growth analysis or something?

MR. MATTHEWS: At the time that they shut down.

CHAIRMAN FORD: What Jack was saying is at this particular time now with current cracks as they are now, they are safe. It doesn't say what is going to happen in the next fuel cycle if you don't know how much it is going to grow.

DR. WALLIS: But that's the whole thing that matters.

CHAIRMAN FORD: That's what we are going to discuss.

MR. BAMFORD: In two slides, we are going to cover that.

DR. WALLIS: But that's the key thing, isn't it?

MR. BAMFORD: Yes.

CHAIRMAN FORD: Could I suggest that -- because this might take a wee bit of time. Could I suggest that we take a quarter of an hour break, and we will adjourn for 15 minutes.

(Whereupon, the foregoing matter went off the record at 10:13 a.m. and went back on the record at 10:32 a.m.)

CHAIRMAN FORD: I would like to bring the meeting back to order. Larry, would you like to continue on the glorious subject of crack growth.

DR. WALLIS: I'd like to bring up -- go back to 66, having thought a bit about it.

(Slide change)

DR. WALLIS: About the cold plants and the hot plants. You said the ones on the right are cold plants, 550 degrees instead of 600. That's why they are on the right.

This is a five percent difference in

ranking temperature. So if we have a five percent difference in activation energy -- If a cold plant has, let's say, 55 kilocalories per mole instead of 50, wouldn't that make it equivalent to a hot plant?

MR. MATTHEWS: Well, it's absolute temperature and not --

DR. WALLIS: It is. That's right. It's only a five percent difference in absolute temperature. So the only point is that the uncertainty in activation energy would move these points around a lot.

MR. MATTHEWS: Well, we had the sensitivity -- We did a 20 percent sensitivity study.

DR. WALLIS: But that's assuming they all have the same activation energy. They have differences in activation energy between plants.

MR. MATTHEWS: Why are you going to have a difference in an activation energy for --

DR. WALLIS: I just don't know. But how close are the activation energies likely to be? I just don't know what the scatter is likely to be.

MR. MATTHEWS: Yes, there's the sensitivity where we went down to 40.

DR. WALLIS: On 64, which we skipped over -- That assumes they are all same activation energy.

The point is, if there is a scatter in activation energy between plants -- I just don't know how certain you are. Seems to me that the number for activation energy is uncertain, to some degree.

MR. MATTHEWS: I guess I would expect it to be the same kind of uncertainty for all the plants, though.

DR. WALLIS: Yes, but it's uncertain. The point is there is an uncertainty. That uncertainty could make a cold plant like a hot plant, if it's only five percent. That's the point. MR. MATTHEWS: Can you address that?

MR. BAMFORD: One of the things that comes out when you start looking at these things is the difference between susceptibility between a 550 and 600 degrees F. is almost two orders of magnitude. So the sensitivity to the temperature is very high.

DR. WALLIS: No, but assuming the same activation energy --

MR. BAMFORD: Well, the sensitivity is a function of the activation energy, and we looked at a different activation energy. Probably, we should show that slide to see what the impact is, because the impact turned out to be small.

DR. WALLIS: No, but that's assuming it's the same between plants. The point is, if --

MR. BAMFORD: Well, you could look at it as different --

DR. WALLIS: -- the activation energy of Oconee is 50, all it has to be is 55 for a cold plant, and the cold plant becomes like Oconee. Isn't that --

MR. BAMFORD: Well, it's the other way around. It would be 45.

DR. WALLIS: Whichever way it is. Forty-five, yes. Or it's supposed to be a five percent effect or -- It's a five percent effect, rather than a ten percent effect. So it's 47 1/2.

Just look at degrees Rankine. Five percent in degrees Rankine is equivalent to five percent in activation energy, and what is the reasonable uncertainty in activation energy?

MR. MATTHEWS: I guess the uncertainty in the activation energy is not the same, in my mind, as the variability from plant to plant.

DR. WALLIS: Same thing. I mean, think of it as the same thing.

MR. MATTHEWS: I guess I don't. The uncertainty is how well do you know the activation energy for stress corrosion cracking in Alloy 600.

DR. WALLIS: Okay, for anything. There's

two questions. Do you know it at all, and how much does it vary between plants?

MR. MATTHEWS: I guess the biggest part of the uncertainty I always envisioned would be how well you knew it, not how much that variable would vary from plant to plant.

DR. WALLIS: Well, it's completely out of my field. I don't know what -- how well you know something like activation energy. Is it likely to vary five percent between plants? Ten percent? Hundred percent? Fifty percent?

MR. FYFITCH: Let me just add something. Steve Fyfitch from Framatone.

If you look at historically all the test data on Alloy 600, whether it be bar material, wrought material, rod material, any kind of product of Alloy 600, for stress corrosion cracking under primary water conditions, the range of activation energies that have been published for crack initiation are in the range of 40-50 kilocalories. Okay?

DR. WALLIS: So it's an uncertainty of maybe ten percent or so?

MR. FYFITCH: In that range, yes, about ten percent. If you look at the range in activation energies for crack growth, they are, you know, 35 to

50 maybe, maybe even less than that.

MR. BAMFORD: Yes, I would say 30 to -- maybe 33 to 36, something like that, for crack growth. What we're really trying to do here is focus on crack initiation.

DR. WALLIS: But the point is then that your graph is based on the same activation energy, and there's an uncertainty in activation energy which is quite capable of moving the cold plants to be like hot plants.

MR. FYFITCH; It wouldn't be that bad, though. I mean, if you do the calculation, for a 50 kcal/mole activation energy, it's 600 degrees versus a 40 kcal/mole activation energy at 550, the numbers don't change that drastically.

DR. WALLIS: That's the whole point.

CHAIRMAN FORD: I think you had two questions. First of all, would you expect the 50 and the 40 or whatever to be absolute values, and for a given phenomenon --

DR. WALLIS: That's less important than, I think, the variability between plants.

CHAIRMAN FORD: Well, the variability between plants, because there are different conditions in the plants.

DR. WALLIS: Because everything is benchmarked to Oconee, it doesn't really matter what the values are. What matters more is the scatter between plants, variability between plants.

CHAIRMAN FORD: For this sensitivity study we did where we changed the activation energy from --

DR. WALLIS: Would you write down this Arrhenius equation, just to see -- show that when the temperature changes and the activation energy changes, you get the same number? They change in certain proportions.

MR. MATTHEWS: It's E to the -Q over RT.

DR. WALLIS: It's in Appendix by five percent and T changes by five percent. Then you get the same number, right?

MR. MATTHEWS: Right.

MR. BAMFORD: And the development of the model is in Appendix B of our interim report that was submitted in --

DR. WALLIS: We don't need it. As long as we know we've got this equation, then we're saying that a five percent uncertainty in activation energy -- a five percent variability between plants in activation energy is like a 50 degree change in temperature.

MR. MATTHEWS: Well, one thing about this study we did, the Oconee plants operate very close to 600. So the adjustment to their EFPY from 602 to 600 is pretty small. If you take the plant that's out in the far-out category and adjust their number from 550 or 560 to 600, it's a pretty big adjustment to stretch their time out.

If you drop that activation energy to 40 kilocalories per mole, Oconee's adjustment is still going to be very small; whereas, that other plant then gets a significantly different adjustment, and that's kind of what this effect would say.

The adjustment for Oconee being the base unit, it wouldn't move very much one way or the other, because it's pretty close to 600.

DR. WALLIS: Well, it's the base unit. It's not going to move at all. Everything is hung on it.

MR. MATTHEWS: Well, I mean, as far as if you're calculating the --

DR. WALLIS: Zero is Oconee on your graph.

MR. MATTHEWS: Right, Oconee-3.

DR. WALLIS: It's just that you can jiggle the other points tremendously by giving --

MR. MATTHEWS: And what I'm saying is that by looking at the sensitivity -- look at the sensitivity study. Oconee wouldn't change their EFPY very much by going from 602 to 600, if you went from 50 to 40. It's not a big adjustment. It's a very small adjustment in temperature, small factor on their EFPY.

A plant that is at 560 gets a big adjustment. It shoves them way out in time. If you dropped it to 40 kilocalories per mole, yeah, it's a significant bump up. But if you look at what it does to the histogram, and those plants are so far out that it still doesn't get them into very near time frame for --

DR. WALLIS: That's because time is also short for them. Right?

MR. MATTHEWS: Right.

DR. WALLIS: Right, but the rate is the same. Yeah.

MR. BAMFORD: I think we should also mention a couple of other things. Setting aside the model, the actual temperatures at the plants are very well known. In other words, the head temperature of the plants -- there's very little --

DR. WALLIS; Absolutely.

MR. BAMFORD: -- uncertainty there. Okay.

But now the other thing that's really important to keep in mind, if you look at the available information from labs and actual tests that have been done, when you get down to temperatures that are in the 550 to 560 degrees range, it's very difficult to get stress corrosion cracks to propagate at all.

In fact, some labs have claimed that below 550 there is no stress corrosion cracking in inconel or in Alloy 600. I'm not so sure that we would go that far, but there's a huge difference in the susceptibility when you get to a lower temperature.

So the plants that are at the lower temperatures are far, far less susceptible than the ones that are at the highest temperature. The highest temperatures -- I've done a lot of lab testing of this material, and at the highest temperatures you can get cracks to grow quite quickly, but at the lowest temperatures it's very, very difficult.

So I think we need to keep that in mind, too, as well.

DR. KRESS: Are you saying that the Arrhenius relationship no longer applies at the lower temperatures?

MR. BAMFORD: No. I'm saying it does apply, and the Arrhenius model is a very good representation of what we actually see in the labs. But the contention that a five percent change in temperature for a plant that's at 550 could put them into a much higher susceptibility area, while that is in fact true according to the model, we know the temperature of the operation quite well, and we also know that low temperatures, down in the 550 range, are very, very unlikely to show stress corrosion cracking unless you have long, long times of service.

DR. WALLIS: Essentially saying the activation energy is very unlikely to be below a certain value.

MR. BAMFORD: I believe that's another way of saying it. That's right.

MR. MATTHEWS: Given that activation energy or whatever it is, the ten years here that we've used -- if you think about what that really means, plants beyond ten years have operated in an effective time at temperature less than half the time that Oconee has.

If you go further out, you know, 30 years, that's ten years before Oconee started up. So it's a significant amount of time that we are tacking on here for our recommendations for inspection.

(Slide change)

MR. MATTHEWS: Circumferential crack growth: One of the things that's been a concern is how fast do these cracks grow, the circumferential cracks, once they get into the annulus environment.

We've got data from five available sources of carefully controlled PWSCC tests of the Alloy 600 and the 182, using PWR conditions. OD initiated cracking requires water or steam in that annulus, and a pressure boundary leak is necessary for that to get there.

Crevice region could contain some oxygen from the containment atmosphere, but at temperature this oxygen would be fairly quickly consumed with the low alloy steel nearby. This reaction, plus the extremely tight fit and the distance to the OD of the head, make a high oxygen environment seem unlikely.

(Slide change)

MR. ROSEN: One moment. If the oxygen is consumed, as you suggest, would it not be replenished?

MR. MATTHEWS: Would it what?

MR. ROSEN: Would it not be replenished by diffusion from the containment atmosphere into the crack?

MR. MATTHEWS: Yes. Over time that's the only way it could get in there, and it would have to diffuse upstream.

DR. WALLIS: Well, if there is no leak, there is no stream.

MR. MATTHEWS: Right. Well, if there's no leak, it's going to be hard to get the oxygen in there, I think.

The circumferential crack growth rate: Since the fluid contains lithium hydroxide and boric acid in this region, it's likely to be similar to a controlled PWR environment. The comparison of --

CHAIRMAN FORD: Before we get into that one, surely the primary liquid is boiling?

MR. MATTHEWS: Yes.

CHAIRMAN FORD: Therefore, you have something like a 30 percent lithium hydroxide solution.

MR. MATTHEWS: Yes. It could concentrate.

CHAIRMAN FORD: What you don't have in the primary environment -- You sure has heck don't have 30 percent lithium hydroxide.

MR. MATTHEWS: No.

CHAIRMAN FORD: So you have a very much more alkaline solution in the annulus, do you not?

MR. MATTHEWS: You've got the acid in there, too.

DR. WALLIS: You've got lithium borate, haven't you?

CHAIRMAN FORD: Yes, but you're doing simple titration. You don't know that it's -- they are equilibrating each other. It's a weak acid and a very strong base.

MR. MATTHEWS: Yes, it is a strong base.

CHAIRMAN FORD: I'm just questioning that, and it's not just an academic debate, because you then go on to say that the disposition curves that you are developing from -- that have been developed, the primary side, apply to the circumferential cracks on the OD. It's based entirely on that assumption in that first bullet.

MR. MATTHEWS: Well, comparing the crack growth data from both the BWR and the PWR environments, a highly oxygenated environment --

CHAIRMAN FORD: Well, I don't debate the second bullet.

MR. MATTHEWS: Okay.

CHAIRMAN FORD: It's the first bullet.

MR. MATTHEWS: That in a caustic environment it would potentially grow significantly.

CHAIRMAN FORD: Are we looking here at two things? Before you actually get a through-wall crack

-- Before you actually get a leak, things are at PWR environment. As soon as you get a leak, you start boiling off the steam, you get a very concentrated solution.

So after you get a leak, things could happen in a different environment altogether.

MR. MATTHEWS: I guess I've heard some people don't really believe it would be significantly different in that environment. The stuff is going to get out.

MR. FYFITCH: Let me add something. Steve Fyfitch, Framatone.

Certainly, you can debate what the environment is in that annulus region. Remember, we are talking a shrink fit that opens up into a counter-bore area. In that counter-bore area where the cracking will be occurring, it's through a very tight crevice. So you have to look at it from a corrosion crevice standpoint.

So initially you would expect that to be essentially primary water.

CHAIRMAN FORD: Correct. But time zero, primary water.

MR. FYFITCH: And with time it may change. With time it may not change. But we haven't really studied that in detail. Nobody has tried to mock it up. Nobody has really looked at that in a lot of detail.

So at this point in time, I don't think we can really debate whether it's a primary water environment, a BWR environment or a concentrated caustic environment.

DR. WALLIS: Well, it's never BWR water in the crack, once you've got a leak. Stuff is flashing and boiling and steam is driven off very rapidly.

CHAIRMAN FORD: And you've got acid crystals. I mean, what you are seeing, you're seeing visual evidence of a concentrating mechanism.

MR. FYFITCH; On top of the head.

CHAIRMAN FORD: Presumably from the bottom.

MR. FYFITCH; On top of the head.

DR. WALLIS: Well, what's in the crack? It doesn't flash at the top of the crack. It flashes at the place where it's pinched down the most, which is the bottom of the leak.

MR. FYFITCH: Right, but it doesn't always condense --

DR. WALLIS: -- through the weld, and flash is in the cracks. The crystals form in the shrink fit.

CHAIRMAN FORD: I guess the very fact that there was -- is indicating there's a question.

MR. FYFITCH: Yes, and I totally agree.

CHAIRMAN FORD: And then the answer to that question has got very large ramifications, because you are using the disposition curves developed in the PWR environment to disposition the cracks which are going on the OD. Correct?

MR. BAMFORD: That is essentially true, but you have to keep in mind that over the years we've gotten -- we've inspected over 6,000 penetrations, and of those some four percent have been found to be cracked. All right? And all of the cracks have been axial except for the very first crack, which was at Bugey-3, and two of the cracks -- I guess three cracks at Oconee unit 3 and maybe one other one. But there's only a couple of circumferential cracks that have happened, and these two cracks that are through-wall at Oconee unit 3 are the only two where the question about the crack growth rate would be relevant.

CHAIRMAN FORD: But aren't those --

MR. BAMFORD: The other ones are all axial, and they have all been part-through. We have only had -- We've only had these leaks that have been found in the last six months plus the one at Bugey.

CHAIRMAN FORD: But aren't the circumferential cracks on the OD above the J-weld -- aren't those the ones which are the greatest safety concern?

MR. BAMFORD: Absolutely, that's true. But there are only two -- three.

CHAIRMAN FORD: Regardless of whether there's only two so far, regardless of the number, those are the ones that we should really be concerned about the absolutely veracity or defensibility of the disposition curves.

MR. BAMFORD: We agree with you.

CHAIRMAN FORD: And, therefore, you better be dark sure that you are developing that disposition curve in the right environment.

MR. BAMFORD: We agree. That information doesn't exist right now.

DR. WALLIS: Right. So you're guessing.

MR. BAMFORD: We are taking educated guesses, yes. You could say that.

DR. WALLIS: Well, that's what we are doing, too, you know.

MR. BAMFORD: We are all in this together.

DR. WALLIS: Yes, but it seems to me that there should be an analysis performed: What happens in the crack with boiling lithium hydroxide? CHAIRMAN FORD: It's not an easy experiment to do, but it's an experiment that could be done.

DR. WALLIS: But you could also do some analysis.

CHAIRMAN FORD: Then the question comes out: What's the impact of this on the safety aspect? I've interrupted too much.

DR. WALLIS: Well, yes, if it does have a big impact, then it's not good enough to guess, seems to me.

MR. MATTHEWS: Some of the data that we got on -- I guess it's on the next side. If we use the crack growth rates that are typical of the PWR environment, we've had two totally separate analyses. One was kind of bounding on crack growth rate from data that we've seen, and I guess I've got the wrong slide up for that.

(Slide change)

MR. MATTHEWS: If you look at the Oconee nozzles, which were cracked --

DR. WALLIS: I'm sorry. When you say temperature is a stronger variable than environment, have you allowed the environment to vary up to --

MR. MATTHEWS: Well, that was comparing the BWR to the PWR environment.

DR. WALLIS: -- 30 percent lithium hydroxide or whatever?

MR. MATTHEWS: Those tests haven't been conducted.

DR. WALLIS: There is no information whatsoever on crack growth rate?

MR. MATTHEWS: Wasn't there some test at higher concentrations?

MR. BAMFORD: We have done a series of crack growth tests where we varied the boron concentration in a PWR environment and varied the lithium concentration. We got -- My recollection is the lithium concentration ended up about 50 percent higher than the nominal, and we found that there was no impact on the crack growth.

DR. WALLIS: We are talking here about many, many percent higher, aren't we?

MR. BAMFORD: Well, we're speculating that it could be many, many percent higher. I guess what we need to figure out is whether that is, in fact, true or not. Your point is well taken.

DR. WALLIS: Well, I think rather than speculating, we are saying that when you flash off steam, it will be. I don't think we're speculating. At some point you are going to get very concentrated solutions. You have to.

MR. BAMFORD: Well, the question really is does the solution when it flashes to steam automatically concentrate itself or does it not?

The experience with the boron, a part of it at least, if you look at the evidence, is that the boron seems to not deposit itself in the crevice. It seems to deposit itself only when it gets to the atmospheric pressure when it gets up to the top of the head.

DR. WALLIS: People have popped these things apart and found that there is no boron in the crevice.

MR. BAMFORD: Very little compared to the boron on the head, I believe.

DR. WALLIS: Well, it's a very small crevice, yes.

MR. BAMFORD: I agree.

MR. MATTHEWS: They have opened -- The evidence that I've heard about is a leaking flange or something like that. The boron deposits are on the outside. They are not actually open --

DR. WALLIS: Well, actually, open leak is going to blow the deposits out, but if it's little leaks, starts as a little leak --

MR. MATTHEWS: No, I'm talking about weeping flanges. The boron is on the outside. it's not deposited in the crack there.

CHAIRMAN FORD: And we know that for a fact?

MR. MATTHEWS: Well, I've heard that. I haven't gone and looked at it, but that's what I've heard people tell me.

MR. BAMFORD: But our evidence is that -- we have not seen evidence that high concentrations of lithium cause accelerated crack growth. Now you can argue that we haven't gone to super high concentrations of lithium, but we have gone to higher concentrations than the nominal, and we don't see an impact, and our judgment is simply based on that, because that's all the information that is available at present.

MR. MATTHEWS: We had two different analyses that have been done of the Oconee flaws that were at 165 degrees to calculate how long they would have had to reach the code allowable with a safety factor of three. In both cases, it was in the four to five year range.

Admittedly, the crack growth rates -- one was a kind of a bounding crack growth rate on lab data, and the other one was the modified Peter Scott model that we have been using for years.

CHAIRMAN FORD: Now the Peter Scott model, just form my remembrance, is based on the estimated crack growth rates observed in steam generator tubes, the primary site.

MR. MATTHEWS: But it's been modified in the process by the industry over the years for this base metal of the head penetrations. That was the model that was used in our earlier responses to --

CHAIRMAN FORD: Now what was the basis for the modification?

MR. MATTHEWS: Warren?

MR. BAMFORD: Lab data on 17 heats of Alloy 600.

CHAIRMAN FORD: Okay.

MR. MATTHEWS: Not tube data.

MR. HUNT: It has also been correlated with EDF cracking experience, too, Ringhals cracking experience.

MR. MATTHEWS: Okay? So even if we're off, they still had significant amount of time there to get to the code margins, and then to get on down to an ejection at operating pressure, there's still a lot more margin left for those penetrations.

CHAIRMAN FORD: That is all reasonable, assuming you don't have really concentrated lithium hydroxide.

MR. MATTHEWS: That makes it grow significantly faster.

CHAIRMAN FORD: Which you would assume based on United Kingdom data for the fusion reactors.

MR. MATTHEWS: Yes.

CHAIRMAN FORD: But for this particular material under these particular circumstances, you know, it's an assumption so far.

DR. WALLIS: Where does the lithium come from?

MR. MATTHEWS: It is put in for pH control in the water chemistry.

MR. SIEBER: But it's more volatile than the boric acid. So I would expect that the crack environment would become acidic as opposed to basic.

CHAIRMAN FORD: Yes, that's right. Let me ask a question. With this uncertainty about the effect of lithium hydroxide -- the concentration, whether it exists, and then if it does it, how much does it increase the crack growth rate? -- how much margin do you have? If it increased the crack growth rate by an order of magnitude, would you expect -- How would that affect your safety analysis?

MR. MATTHEWS: I guess if the crack growth rate was ten times faster, it would have cut down on the amount of time that a flaw as big as Oconee 3's would have had from four to five years to significantly less than four to five years. I haven't got the numbers, but an order of magnitude is a factor of ten, I guess.

CHAIRMAN FORD: Why do you say four to five years? Where is that coming from?

MR. MATTHEWS: Well, if we use the Peter Scott model or the other way we did it with the bounding crack growth rate data, 165 degree flaw had four to five years before it could have propagated to the point where we would have barely met code margins, and even more time than that before it could have gotten to the point where we only had like a 30 degree ligament left and could have resulted in an ejection.

DR. WALLIS; It seems to me, there's a very interesting question here. I mean, your shrink fit may be actually saving you, because it may be allowing you to leak fast enough that you don't build up a concentration of lithium. Worse situation is a crack growing with a very small leak.

So the crack growth and the leak rate and all these are all tied together, and it would seem to me someone has got to analyze all these interrelated things and figure out what's likely to happen.

MR. MATTHEWS: Trying to get there.

DR. WALLIS: Yes, but you have this very crude model based on Arrhenius with one constant.

MR. MATTHEWS: Well, that model is not a predictive model. All we are trying to do with that is rank the plants to figure out -- We don't have much data, and we're trying to rank the plants to figure out which ones ought to be the ones to go take a look to give us some more data. That's where we are.

CHAIRMAN FORD: And there's no argument with that. Now just coming back to this lithium hydroxide, you mentioned earlier on, Warren, that with Bugey-3 you did some subsequent inspections. Or did you say it, that they had done some subsequent inspections on the OD cracks? If so, what was the average crack propagation?

MR. BAMFORD: Well, there was only one crack at Bugey-3, and it was removed. So they never did any follow-up inspections there. But there have been other follow-up inspections at other plants.

CHAIRMAN FORD: And?

MR. BAMFORD: But keep in mind that we only have two -- We have the little small circumferential crack that was removed at Bugey-3, and we have these two circumferential flaws at Oconee that were through-wall and leaking, and maybe there's a third one, a small one at Oconee. But we don't have multiple measurements of the cracking of these circumferential flaws.

MR. MATTHEWS: All the circ flaws in a leaking environment have been repaired immediately, as I recall.

MR. BAMFORD: Yes. We would not be interested in leaving a circumferential flaw in service.

MR. MATTHEWS: It's not the place to get this data.

CHAIRMAN FORD: Okay, thank you.

(Slide change)

MR. MATTHEWS: The next slide is on loose parts. Basically, if you have enough flaws -- I'm going to skip it -- If you have enough flaws, axial and circumferential, below the weld hook-up, the potential is there, although we feel it is quite low, to create a loose part.

Basically, the worse consequence from that that we see is a stuck rod from that one -- one stuck rod from that loose part, and --

DR. UHRIG: There would be a leak?

MR. MATTHEWS: No. No, you could create a loose part without creating a leak, if all the cracking is going on below the weld. But the worst consequence is any other kind of loose part up in that region, you could possibly jam a control rod with a loose part. The probability, we're going to get more than one before you find that one is pretty low.

DR. UHRIG: As I recall, Oconee had loose parts monitors. Am I correct on that?

MR. MATTHEWS: On the vessel?

DR. UHRIG: No, I think it's just in the steam generators.

MR. MATTHEWS: Well, he's nodding his head. One of the most probable places for a loose part that's generated here to go is the steam generator, yes.

DR. UHRIG: That's the ones I'm most familiar with.

MR. MATTHEWS: And that would be picked up.

(Slide change)

MR. MATTHEWS: From a risk calculation -- We have risk calculations that are now in process. The efforts include interaction with all the PWR vendors to make sure it's applicable to all the plants.

It is going to be consistent with some of the past approaches we have taken. WE have heard the staff has conservatively estimated a conditional core damage probability at about 10^{-3}, assuming a rod ejection. That would be, I guess, consistent with a small break LOCA or medium break LOCA.

I heard today they may have a number that's quite a bit higher, and I'm not sure how they got that. But we feel the probability of ejection event is likely to be a few orders of magnitude less than 1 certainty. So the probability is going to be getting down into -- or the core damage frequency from rod ejection because of this is going to be, we feel, quite low, but we haven't finished the analysis to prove that yet.

DR. KRESS: How do you calculate the probability of rod ejection?

MR. MATTHEWS: What do they call it, probabilistic fracture mechanics is one of the things, plus they are going to look at the --

DR. KRESS: So you do have to put in the uncertainties?

MR. MATTHEWS: Yes.

DR. KRESS: Crack growth and certainly, strength and -- When the thing goes, it's like a pressurized thermal shock.

MR. MATTHEWS: I believe all that will be in there.

DR. WALLIS: But we don't have lithium and stuff in the --

MR. MATTHEWS: We would have to account for it in the uncertainty.

DR. KRESS: You have to put that in the uncertainties, don't you?

(Slide change)

MR. MATTHEWS: I am get to a summary. This is the same one I had up front. Okay? Why I put it up front -- I wasn't sure I was going to get here.

Axial cracks alone in the CRDM nozzles do not impact plant safety. We didn't fix that first slide. We should have.

DR. WALLIS: These are the cracks which might be spiral cracks?

MR. MATTHEWS: They could be 45 degree

cracks, but by the time they got to where the thing could eject, there would be a lot of leakage, I'm sure.

CHAIRMAN FORD: Now we didn't address this in the presentation, this particular aspect, and I'm assuming from the staff's point of view that's an okay statement. Yes?

The very first bullet there, we didn't address this during this presentation from a technical point of view. I'm assuming that is an accurate statement.

MR. STROSNIDER: Yes. Just briefly with regard to axial cracks, I think if you go back and look at the work that was done in the mid-Nineties and Generic Order 97-01, a large part of the basis for our accepting the susceptibility model and the industry proposed inspections at that time was because of the low safety significance of axial cracking.

The critical flaw sizes are very large, and --

DR. KRESS: That is based on the fact that it just leads to a LOCA model rod ejection?

MR. STROSNIDER: The circumferential crack changes the complexion of the problem considerably, because of the potential for LOCA. We did acknowledge that potential back in some of the safety evaluations that were written, in fact pointing out that if this sort of thing came up, the industry needed to inform the NRC and it would have to be dealt with. So that's where we're at now.

DR. WALLIS: Could we go back to definition. An axial crack is something less than 45 degrees from the axis?

MR. MATTHEWS: That is what we have kind of used.

DR. WALLIS: And when it becomes 46 degrees, it becomes a circumferential crack?

MR. MATTHEWS: Go ahead.

MR. STROSNIDER: This is Jack Strosnider again. Actually, referring to some of the safety evaluations that were written back in the mid-Nineties, there was actually an agreed upon definition, if you will, of anything more than 45 degrees off axis would be considered circumferential.

DR. WALLIS: This is very strange. I mean, a crack which is, say, 44.9 degrees is okay, but if it becomes 45.1, it suddenly becomes a terrible thing because it's circumferential?

MR. MATTHEWS: An axial crack will lead to a leak. That's where it can ultimately come to, is a leak, but it cannot lead to a major rupture of the pipe. It just can't get that long.

DR. WALLIS: Well, I don't understand this, and there's nothing magical about 45 degrees.

MR. MATTHEWS: Well, that was just a definition.

DR. WALLIS: It can be 42 or some other number.

MR. BAMFORD: I think we need to keep in mind, though, that the cracks are predominantly either 100 percent axial or they follow the profile of the weld because of the stresses.

DR. WALLIS: This is misleading, this talk about axial and circumferential. It gives the impression that it's either this way or that way, 90 degrees.

MR. BAMFORD: No, but that's the experience. That is, in fact, the experience. You don't have a family of cracks. It could be any orientation. The cracks orient themselves perpendicular to the maximum principal stress.

DR. WALLIS: But you don't know what that is.

MR. BAMFORD: In most of the -- That's right. The evaluations that we've done have shown that the maximum principal stress is hoop stress. All right?

Now what happens is at the very top of the weld, then you end up with a situation where the hoop stresses decrease very quickly as you go above the weld, and the axial stresses that are there from the weld itself stay high right along, right at the top of the weld. That seems to be consistent with what's happened with these two cracks that we have seen in Oconee, that they follow that. They stay in the high stressed area.

DR. WALLIS: Here are your arguments about stress are based on these residual stresses from the welding operation?

MR. BAMFORD: Correct. From the evaluation -- From the multiple evaluations that we've done and where we have compared a number of different calculations and found consistent results.

DR. WALLIS: I thought we discovered earlier that models based on that didn't work out very well. So we don't really know too much.

MR. BAMFORD: I am talking about finite element stress analyses, and they are pretty well understood and --

DR. WALLIS: -- go back to how the thing

was welded, and they figure out the residual stresses from the history of how it was welded. Is that what happens in the finite element analysis?

MR. BAMFORD: That's correct. In fact, the actual welding of the head penetration is modeled into some of the finite element results.

DR. WALLIS: This is -- technology. so we can believe the answer?

MR. BAMFORD: Yes, and we've gotten multiple results that were consistent. So we have a lot of confidence in the residual stress calculations.

DR. WALLIS: To go back to the first issue, what is axial and what is circumferential, it seems to me you have to use words which describe the reality and aren't misleading. I got the impression that axial cracks were one direction, and circumferential were 90 degrees.

There are real cracks which are at all kinds of angles.

MR. MATTHEWS: Well, most of the cracks that have been observed have either been pretty much axial or have a significant circumferential component, and the ones in --

DR. WALLIS: Nothing in between? Nothing in between?

MR. MATTHEWS: Not a lot. The ones at Oconee tended to follow the weld profile with circumferential -- major circumferential cracks.

MR. STROSNIDER: This is Jack Strosnider. I guess I would just make the comment: Maybe that wasn't the best definition in retrospect, but the intent -- The intent was to identify the potential for a crack that could run around such that the tube could be ejected. That was the concern, and that's what that was driving at.

Now when you start looking at the axial geometry and the orientation of these cracks because of hillside and one thing or another, it may not have been the best definition. But the intent was to look for those sort of cracks that might lead to a guillotine failure of that penetration.

DR. BONACA: I seem to have read somewhere in the material, not from this presentation, that circumferential cracks were observed where multiple axial cracks with some kind of, you know, radial initiation then merged into one common circumferential crack, then moved across. There was the result of multiple axial cracks.

MR. MATTHEWS: I think that has been a hypothesis as how one of the circ cracks at Oconee may have grown, but I'm not --

MR. ROBINSON: Larry, this is Mike Robinson again. On Oconee 3 one of the nozzles that did have the circ crack in it, we were able to remove a sample of a circ crack and look at it in the lab. Part of the sample that we did take, when we put it in the lab and examined it, we did identify several axial cracks that actually intersected with the circ crack.

DR. BONACA: All right. That's what -- But it is not the only way you are going to get circumferential cracks. You are telling me that there are other ways in which they can develop.

MR. MATTHEWS: If you can get coolant corrodant into the environment where you have the high axial stresses, it should grow circumferentially also.

MR. MATTHEWS: I've already talked about this. We believe there's reasonable assurance that PWRs do not have circumferential cracking that would exceed the structural margin.

DR. WALLIS: What does reasonable assurance mean?

MR. MATTHEWS: I haven't got a number. We feel pretty confident that the program we have to go out and see how bad the problem is is the right program.

DR. WALLIS: But if someone else feels less confident, how do you convince them?

MR. MATTHEWS: We go through a lot of detail about that it will leak. There's plenty of margin at Oconee.

DR. WALLIS: And then you calculate some number which gives you assurance?

MR. MATTHEWS: I don't have a number. I don't think we've done that.

DR. BONACA: But the consequence of these conclusions is that a large number of units will not perform the inspections between now and next spring?

MR. MATTHEWS: Yes.

DR. BONACA: Is there any plan for when they are going to be performing inspections or you just simply left to -- I mean, there is a lot of stuff hanging on these assumptions and conclusions and confidence.

MR. MATTHEWS: Well, we have recommended that all the plans less than ten years do a visual at their next refueling outage and, like we showed on the curve, that is going to pick up all but two plants by next spring will have done a thorough visual of the top of their head, less than ten years.

DR. BONACA: Yes, about 25 plants.

MR. MATTHEWS: Yes.

CHAIRMAN FORD: So should that sentence be revised, and the question is the time: Reasonable assurance would exceed structural margin before spring '02 or within the next ten years?

MR. MATTHEWS: It's before spring '02. We are not trying to nail down anything very far out in the future. We are trying to set a program that's going to get us some information on what the status is.

DR. BONACA: Not before '02. I mean, this family of plants is going to be only about 25, not all of them.

MR. MATTHEWS: Yes, it's not all the plants. It is the ones that are less than half the life of -- more than half the life of Oconee on the time at temperature.

DR. WALLIS: If you were to make a bet on this, the reasonable assurance, what sort of odds would you give?

MR. MATTHEWS: I don't have a lot of money.

DR. WALLIS: It's just a probabilistic question, just a question of probability.

DR. BONACA: You know, I get enough

confidence in your presentation to feel reasonably comfortable with the 25 plants. I'm not sure if I'm comfortable on the others.

MR. MATTHEWS: I think the industry was comfortable with the 25 plants as being the lead unit and taking a look at those plants. You know, what we find in the first plant that deviates from what we expect, the whole thing is going to be reevaluated.

DR. BONACA: That makes sense.

MR. ROSEN: What I'm surprised about is that you haven't made any points about plants operating -- that most plants operate for most of the time with all rods out.

MR. MATTHEWS: And that is a very good point. The rod ejection accident or the rupture and ejection of one of these housings for 99.9 percent of the time is not the classic rod ejection accident that occurs in the analysis of reactivity insertion event -- it's just a LOCA, because the rods are operating all the way. It's just a very small LOCA.

The only time it ever would be a problem from a reactivity standpoint is in that very narrow window of start-up or shutdown where the rods have gotten a pattern that resulted in a high rod work that could possibly approach the rod works that were assumed in the rod ejection accident for the FSARs.

DR. BONACA: That's correct.

MR. MATTHEWS: And then on top of that, it would have to be that housing that had the crack, and it would have to eject at that point in time for it to be any kind of reactivity problem. Otherwise, it's just a small LOCA.

CHAIRMAN FORD: I have an associated question from a colleague who wasn't here, Dr. Dana Powers. Let me read it to you, and I ask you guys to help me in the interpretation of the question.

"What do we have on the risk analyses for small break LOCA with failure to SCRAM?" Then subsequently: "Have these analyses treated neutronic effects and the possible effects of high burnup fuel?"

MR. MATTHEWS: We are doing our risk assessment now. I'm not sure I got the answers to the failure to scrim. It's not clear to me why you would get a failure to SCRAM. It would take an awful lot of concurrent damage from that ejection to result in the rods not going in.

Probably, the most likely thing is you are going to destroy the cables, which is going to be one of the fastest ways to get the rods in, in the first place.

The only way you prevent one from going in is to severely deform an adjacent housing, and a foot away from a 2 1/2 inch opening -- I don't have the numbers yet, but to deform one over far enough that the rod -- or the drive rod -- is going to bind and prevent the rod from going in seems fairly unlikely to me. But we haven't finished the numbers yet.

What was the second part of that?

CHAIRMAN FORD: Have these analyses treated the neutronic effects and the possible effect of high burnup fuel?

MR. MATTHEWS: Oh, well, we haven't done them yet. So --

CHAIRMAN FORD: So the answer is no?

MR. MATTHEWS: No.

MR. ROSEN: You said 2 1/2 inch opening.

MR. MATTHEWS: Or I guess it's 2 5/8, the idea of the nozzle. It is a four-inch nozzle, but it's a 5/8 inch long. Two and three-quarters, is that what it is? There's a two and three-quarter inch hole left.

When the top piece goes away, the bottom piece would still be there. If the ejection resulted from a circumferential flaw above the weld, you still got the part that's connected to the weld intact. So you only have a 2 3/4 inch hole in the vessel, and it's got a rod stuck through it.

DR. BONACA: Yes, it's fully open. You got the rod -- Yes.

MR. MATTHEWS: So it's a fairly small LOCA, and the only way you could get failure to SCRAM is severely deform a significant number of other CRDM housings, which are -- 5/8 inch on a four-inch nozzle is a pretty hefty wall on it.

MR. ROSEN: So the most likely thing to happen, if you had an ejection, would be you would have a 2 3/4 inch hole open in the top of the vessel, and there would be no reactivity effect at all -- I mean from the ejection.

MR. MATTHEWS: Well, the SCRAM would be minus the one rod that is surely jammed at the top at that point.

MR. ROSEN: Well, sure.

MR. MATTHEWS: But they always assume a stuck rod.

MR. ROSEN: But there will be no insertion of reactivity.

DR. BONACA: Well, if you drop the rods and you SCRAM, you have effectively equivalent of a rod ejection. I mean, you have one rod failing to

SCRAM -- to insert.

MR. MATTHEWS: Typically, SCRAM -- one rod doesn't go in.

DR. BONACA: -- go down to zero, you know, a lower power level or zero power level where, you know, the rod is worth a lot. So I don't think you can make an analysis of the fly.

MR. MATTHEWS: No. But I think SCRAMs typically assume the -- I mean the analyses assume at least one rod doesn't go in.

CHAIRMAN FORD: Okay, the schedule?

(Slide change)

MR. MATTHEWS: We have some activities ongoing, and I didn't get a chance or somehow I missed talking about a couple of these.

We were reasonably going to get some final inspection recommendations out by the end of June for the plants that are coming down this fall. We kind of delayed that when we heard about there might be a bulletin. We wanted to see where that goes, but we will get recommendations out to the plants on what they ought to be doing in the fall.

We have convened or are convening an expert panel on crack growth. The intent -- That's an international expert panel with people from several countries around and experts from the U.S. to look at crack growth, crack growth rate, crack growth database, what data do we know and where are the holes, and are the holes worth doing the experiments to fill in.

CHAIRMAN FORD: Is this an EPRI sponsored panel?

MR. MATTHEWS: Yes.

CHAIRMAN FORD: Similar to one that was convened for boiling water reactors?

MR. MATTHEWS: I think it is similar to that.

DR. BONACA: Is there any plan to do some testing? I mean, here we have the long discussion that left us with the question of --

MR. MATTHEWS: Well, one of the things out of the expert panel is where do we need more data, and at that point we would fold that into an industry program to go get that data, if it's useful data to go get, if it is going to help.

CHAIRMAN FORD: Now this is different from the NRC expert panel, as I understand it?

MR. MATTHEWS: Yes.

CHAIRMAN FORD: Okay.

MR. MATTHEWS: We have all the inspections that are planned for those units in the fall outages.

The final RPV penetration safety assessment, taking everything we know into account at that point in time, we would plan to get by the end of the year. It would take in account the fall inspections.

Then we would be reassessing and getting new recommendations out before the spring, based on whatever we see in the fall.

I have already covered the other ongoing activities up front.

CHAIRMAN FORD: Is there a timetable for the other activities?

(Slide change)

MR. MATTHEWS: The risk assessments we've started, and we are going to get to them as soon as we can. I'm not sure -- do we have a deadline on that?

Probabilistic fracture mechanics would be in there also. The NDE demonstration: We are working to have some demonstrations of any volumetric techniques that are going to be used this fall. We are working to have those available and demonstrated before the fall.