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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

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JOINT MEETING
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
(ACRS)
SUBCOMMITTEES ON MATERIALS & METALLURGY AND
THERMAL-HYDRAULIC PHENOMENA

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TUESDAY,
FEBRUARY 3, 2004

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ROCKVILLE, MARYLAND

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The Subcommittee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B3, 11545 Rockville Pike, at 8:30 a.m., F. Peter Ford and Graham Wallis, Co-Chairmen, presiding.

<u>COMMITTEE MEMBERS:</u>

F. PETER FORD, Co-Chairman
GRAHAM B. WALLIS, Co-Chairman
MARIO V. BONACA, Member

COMMITTEE MEMBERS:

B.P. JAIN, Member

THOMAS S. KRESS, Member

VICTOR R. RANSOM, Member

STEPHEN L. ROSEN, Member

JOHN D. SIEBER, Member

ACRS STAFF PRESENT:

MAITRI BANERJAN

BILL BATEMAN

CHRIS BOYD

JIM DAVIS

BOB DOWNIG

MICHELLE HART

ALLEN HISER

KEN KARWOSKI

WILLIAM KROTIUK

DAVID KUPPERMAN

STEVE LONG

LOUISE LUND

JOE MUSCARA

JOEL PAGE

WILLIAM SHACK

ROY WOODS

AGENDA

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

8:33 a.m.

CO-CHAIRMAN FORD: The meeting will come to order. This is the joint meeting of the Subcommittees on Materials and Metallurgy and Thermal-Hydraulic Phenomena Subcommittee meeting

I am Peter Ford, Chairman of the Materials and my Co-Chair is Graham Wallis who is the Chairman of the Thermal-Hydraulics Committee.

Subcommittee members are Mario Bonaca, John Sieber, Tom Kress and Victor Ransom.

The purpose of the Joint Materials and Metallurgy and Thermal-Hydraulic Phenomena Subcommittee meeting is to review the staff's resolution of certain items identified by the ACRS in NUREG-1740, voltage based alternative repair criteria. The Subcommittees will review the resolution of the steam generator action plan items which are associated with the differing professional opinion on steam generator tube integrity as well as the status for resolution of remaining items.

The Subcommittees will hear the presentations by and full discussions with representatives of the staff and its contractors and other interested persons regarding this matter on particularly those items in the SGAP which the has staff has closed out.

The Subcommittee will gather information, analyze relevant issues and facts and formulate proposed positions and actions as appropriate for deliberation by the full Committee on February 5th.

Maitri Banerjan is the designated Federal official and the cognizant ACRS staff engineer for this meeting.

And the rules for participation in today's meeting have been announced as part of the notice of this meeting previously published in the Federal Register on January 14, 2004.

A transcript of the meeting is being kept and will be made available.

It is requested that speakers first identify themselves, speak with sufficient clarity and volume so that they can be readily heard.

We have received no written comments or requests for time to make oral presentations or statements from members of the public regarding today's meeting.

Before handing it over to Graham for his personal comments, I'd like to make a couple of requests.

The first is that it is my understanding that we are being asked to write a letter commenting on the closure of some of the items. One of the items I would like to have discussed fairly early on is the criteria which the staff have used for closing out an item. These are all specific items which were brought up in the NUREG-1740 in their very localized interest, however they all take part in an overall marriage of all these tasks.

So my second question is, is the criteria given by the staff to the completion of these various subtasks, does it take into account the overall objective of this whole program, which presumably is an assessment of the risk associated with these various severe accident actions?

Those are my two requests that be covered fairly early on.

Graham, do you have any comments?

CO-CHAIRMAN WALLIS: Well, I have the same concern. I read a great stack of reports and some of these are very interesting. For instance, there's a beautiful CFD representation of a steam generator. But out of this has to come some output. So something has to be predicted in terms of something else, which then goes into the big picture which presumably a PRA of some sort.

It's not clear what the inputs are to this analysis or what the outputs are; where they come from, how they relate to the big picture if it's an accident and here's a little piece of the study which is very nice, but you have no idea how it fits into modeling an entire accident sequence and modeling a PRA.

When I look at the PRA reports they have a structure. They say you've got to consider A, B, C, D in a sort of a very, very general way. There's nothing specific really which says I need this parameter out of somebody else's work and this parameter -- this is how it fits together. Until you fit all of the bits of work together you don't really know that your overall structure for developing the PRA is going to work. So I'd like to see that. I don't see it at all in any of the reports I got.

I don't think you can close out a little piece of this thing and say we've done some CFD until you know that the results of that CFD, what it's able to take as input and what it is able to give as outputs, fit into what you need for the overall structure. You cannot close it off by itself. That's a concern that I have.

I think that there's been some very good work done on the thesis of this, and maybe it's all clear to you guys how it all fits together and you can tell us. Thank you.

CO-CHAIRMAN FORD: Okay. Joe, you got to overall questions; if you could address them to start with and then we'll go into the specific presentation?

DR. MUSCARA: Yes. Good morning.

CO-CHAIRMAN FORD: Joe Muscara of the RES staff.

DR. MUSCARA: Thank you, Peter.

Good morning. I think it's a much better morning, weather wise at least, than was predicated.

Yes, I agree with your questions and comments. And, hopefully, by the time we're finished with our today meeting, it will become much clear how things fit together. And perhaps there's a little bit of confusion on the purpose of this meeting, so maybe in my short overview I'll try to clarify. I'm quite comfortable and confident that the questions will be answered and you will see how the work comes together.

In the last detailed meeting we've had with the ACRS was back in September of 2001. Around that same time frame we developed -- actually updated our task action plan for steam generators, and this was based on the NUREG-1740, that is the ACRS recommendations and comments to address the DPO issues.

And in October of 2001 the ACRS reviewed and endorsed this action plan. Well, since that time considerable research and evaluations have been completed, particularly in the areas of inservice inspection and nondestructive evaluation, on steam generator tube integrity particularly under main steamline break conditions, on thermal hydraulics, on primary system component response during severe accidents, on PRA and also the iodine spiking issue was revisited.

CO-CHAIRMAN WALLIS: Could I ask you then, again, I mean I saw some results from thermal hydraulics and steam generator tube integrity. PRA, I didn't see anyone try to put any numbers into anything or to try to calculate anything. And it seemed to be a general thing. Is a PRA ought to do -- it's sort of like an ASME standard for a PRA.

But that doesn't tell you what you need for this PRA and that you've got it right.

DR. MUSCARA: Yes, precisely. Unfortunately, the PRA work got started a lot later than the rest of the activities.

CO-CHAIRMAN WALLIS: It should start at the beginning because it's the structure under which everything has to fit.

DR. MUSCARA: Yes. And you're precisely correct. And unfortunate that presentation is the last one of the two day meeting. But over the past year a contract has been put in place for us to work on the PRA. The PRA methodology we're using will be similar to what's been used on the PTS issue. And we also conducted an integration effort, which I will talk about briefly as I go on with my few viewgraphs.

So what you have seen, unfortunately, was very initial work on PRA, which was a very general document. We're now getting down to the specifics on what are the inputs and what inputs are coming from and how they'll be used.

CO-CHAIRMAN WALLIS: Yes. And the trouble is if you closed out something, you may find when you do the PRA that maybe you shouldn't have closed it out because it's asking questions which weren't answered in the work that was done and closed out.

DR. MUSCARA: Yes.

CO-CHAIRMAN FORD: When you say on the third bullet down "Considerable research and evaluations have since been completed" and you've got probabilistic risk assessment in that list, that's not true? The PRA has not been completed, or has it?

DR. MUSCARA: Well, I say considerable research work and activities are ongoing. My view, some of it is completed. You know, the PRA analysis is not done. Those things will be finished in '05 and '06. But major pieces of work have been completed. And the idea here was that since the ACRS has not heard from us for quite a while, to give you a progress report. And in that sense I choose some areas where I thought we had enough work done that we could talk about it. And some areas we're not talking about because there just isn't enough work done, or it's to be done in the future, or in fact has been completed.

So what I meant to say there by it being completed, it's completed enough for us to talk about it. It some areas it is complete enough to be closed, and I'll describe that also.

CO-CHAIRMAN FORD: If our letter is to address our approval or comments on items which have been closed out, will you make it clear as we go through the next couple of days which have been closed out and which need a decision or comments from yes?

DR. MUSCARA: Yes.

MR. WOODS: Joe? This is Roy Woods, ACRS staff.

I'm sort of the coordinator of the PRA part of this effort. And on my left here I have Dave Kunsman from Sandia National Lab and Dave Bradley from SAIC. We make the last presentation, but as we go through all this if we can make it more clear how all these pieces fit together, we will.

CO-CHAIRMAN FORD: If you could do, that would be a great help. Because I think as far as Graham and I are concerned, at least, the success of this whole DPO resolution rests on a number which takes into account how much is the risk of radioactivity release, how much has that been increased or decreased given the uncertainties and all the proceeding subtasks.

MR. WOODS: Well, our goal is to put together a method that can be used to establish that risk, calculate that risk for any given plant and to demonstrate that method on a sort of a hybrid plant. It won't be any particular plant.

CO-CHAIRMAN FORD: Good.

DR. MUSCARA: Okay. I think we're getting ahead of ourselves. That's the final thing.

CO-CHAIRMAN FORD: Well, the reason why I'm trying to nail it down now, Joe, is that at least two of the members of these Subcommittees are concerned as to where are we going with this and what are we being asked to approve, disapprove at this particular juncture.

DR. MUSCARA: Well, I guess from our side we're not asking for an ACRS letter. I mean, I consider this being a progress report on our work. And the reason we're having this meeting is because some ACRS members have expressed an interest in hearing from us because they have not heard for a couple of years.

CO-CHAIRMAN WALLIS: So the useful input to you may well just come from reading the transcript rather than from a letter?

MEMBER BONACA: Excuse me. Joe, I think

we have gone over that before. I think we need some of the issues we've said is closed out.

DR. MUSCARA: No. I'm sorry. I have not said the issues are closed. If I can get through my viewgraphs, then maybe we can --

CO-CHAIRMAN WALLIS: Yes. Joe, just talking about the overview, I think it's very important to set the stage because we're going to come back to these questions later.

DR. MUSCARA: Yes.

CO-CHAIRMAN WALLIS: And if your presentations don't address them, we're going to be in trouble.

DR. MUSCARA: I think I will try then --

CO-CHAIRMAN WALLIS: So I think it's worthwhile to take a little while now.

DR. MUSCARA: At the end we'll go on.

CO-CHAIRMAN WALLIS: So I'm going to take not just PRA, but this primary system component response.

DR. MUSCARA: Sure.

CO-CHAIRMAN WALLIS: What I saw again, it's a very nice piece of work on CFD modeling a steam generator.

DR. MUSCARA: Yes.

CO-CHAIRMAN WALLIS: That's fine. But a steam generator is part of the overall circuit, right?

DR. MUSCARA: Yes.

CO-CHAIRMAN WALLIS: And you cannot, it seems to me, analyze the whole circuit with RELAP and then say now we're going to analyze the steam generator with CFD because the CFD predicts the behavior of that steam generator which is different from what -- we cannot predict this kind of current flow and so on, right? So now that new model of the steam generator has to be fit into a system model because now you got to model the whole system knowing what you know now about them steam generator, right? It's not clear to me that you've addressed that problem.

You cannot look at the component separately without seeing how they fit into the whole model. Because as soon as you learn something new about how one component behaves, it may change the behavior of the whole system.

DR. MUSCARA: That's right. And those are the kinds of things we'll be discussing.

CO-CHAIRMAN WALLIS: And that isn't in your reports.

DR. MUSCARA: Okay. Let me address the reports. Again, one of the comments we heard from ACRS was we haven't heard from you. We you have closed out some of these tasks and subtasks, we haven't seen the basis for it. Well, unfortunately, some of the close out letters are not yet to the members. So the idea of the background information we sent you was to give you an update of the work that was done, the tasks that we had closed and the supporting report for closing that task.

Again, I want to stress that these are tasks and subtasks that are closed and not issues.

CO-CHAIRMAN WALLIS: That's very good. I think we're both saying you can't close something until you know what effect it has on other things.

DR. MUSCARA: Okay. Well, sir, let's --

CO-CHAIRMAN WALLIS: It's naive to say because you got a nice model for something that that's done it. Because until you see how it fits in with the other models in some systematic way, it may not be what you need.

MEMBER KRESS: Well, you can close out a task because it has well defined milestones and stuff. And it may not be sufficient to resolve an issue, but you can close out a task. You may have to revisit --

DR. MUSCARA: This is why I'm emphasizing on closing out tasks. And I had a couple of bullets in there, and I think I'll get to get eventually.

MEMBER KRESS: Okay.

CO-CHAIRMAN WALLIS: Well, we'll let you go. But I think you see what we're saying.

DR. MUSCARA: Yes. And I totally agree with you. But I am hoping at the end of the two days, and probably a lot sooner, this will be all resolved.

For this meeting we effectively thought it was a good idea to have the staff and the contractor who actually conducted the work to make the presentations. Because I felt that it was good to have a technical meeting for a change rather than a procedural process kind of meeting.

CO-CHAIRMAN WALLIS: Yes, well done.

DR. MUSCARA: Now, the presentations will emphasize, again, the technical work that's conducted to essentially describe the completion of some of the tasks and subtasks and milestones.

Now, although some of these milestones have been closed, work in some of the these same areas is continuing. And this is based on lessons learned from the prior research and from the refinements we find are needed. Now, in doing this we have also been updating our steam generator action plan so that the action plan, you know, it's a live document. So as we close our tasks and we find we need to do additional work, that task is closed but the additional work is set up and it's identified in the plan.

You know, again, we emphasize we closed tasks. And the reason that these tasks are closed is because is because when you look at the action plan what we've said is conduct X tests. Well, the tests were conducted, the results were reported, therefore that particular task could be closed. It doesn't mean the issue is closed. It means that that specific task when we said conduct a number of tests for leak conversion --

CO-CHAIRMAN WALLIS: This is a bureaucratic danger, though. You sort of set some tasks and when they're done, you say it's finished. We've done our work. Forget it. And, in fact, you may not have solved what you need.

DR. MUSCARA: But what we're doing with these tasks is coming up and developing the building blocks --

CO-CHAIRMAN WALLIS: I understand.

DR. MUSCARA: -- upon which we depend for doing the final resolution. And much of this work we're talking about essentially feeds into the PRA, so that we can at the end of the program have the right data inputs and do a realistic and an acceptable PRA.

CO-CHAIRMAN FORD: So you're looking at this purely as a creation of building blocks so in 2005 you can say, right, here's the building blocks, how you going to resolve future issues and these are the issues that we have to do like kinetic --

DR. MUSCARA: That's right. And this is how the action plan is set up. It's set up in a number of building blocks. And what we're closing out is the building blocks. But if we find that we need to do refinements or additional work, we will close that out but added a new task to do that additional work.

CO-CHAIRMAN WALLIS: As you know, in order for a structure to work the building blocks have to fit together.

DR. MUSCARA: Sure. Sure.

Now the resolution of these issues

really will be based on the staff's utilization of the completed and ongoing research activities which are scheduled in the action plan for 2005 and 2006.

I guess at this point I could mention that some issues we consider, you know, closed not just the specific tasks. For example, the jet impingement issue. That issue has been studied and resolved and we presented to ACRS back in September of '01. And we have an agreement that that issue is not an issue that we need to keep following.

I think based on the information you hear these next two days, and actually will be covered today, the issue about the effects of propagating flaws during a steamline effect, steamline break event, can also be closed. I think we have enough information that indicates that those loads are not high enough to propagate existing flaws to any degree of interest.

CO-CHAIRMAN WALLIS: I'm wondering, again, do you have an objective other than the questions raised by ACRS? I mean, is the objective to develop a risk measure for all these things? Is that your measure? I don't think that's necessarily what the ACRS asked for. We simply said here are these problems you ought to investment.

Does your purpose go beyond that and say we're going to develop risk measures of all these things?

DR. MUSCARA: There are a number of activities that we are working on steam generator research and issues. One of the key activities has to do with developing some information on the potential for containment bypass. That's where we've done most of our integration work and where the PRA at this point is addressing. So it's addressing the potential for the containment bypass during severe accident.

CO-CHAIRMAN WALLIS: So is it fair to say that the output of all this work is going to be something in a PRA?

DR. MUSCARA: It's fair to say that much of the work. For example, one of the issues that ACRS had had to do with our poor understanding of stress cracking. Now we're doing work in that area. That work goes on beyond the resolution of the containment bypass.

CO-CHAIRMAN WALLIS: But the ultimate question really is what is the risk associated with something like a main steamline break? Isn't that the main sort of question?

DR. MUSCARA: That's one key issue that you've had, and we'll address that at this meeting.

CO-CHAIRMAN FORD: Is it possible, Joe, that is a very interesting point. I gathered that by reading some of your notes in the SGCB that there are other projects ongoing, like this containment bypass. Is it possible for tomorrow before we go away and have to make some decisions, just give us one viewgraph of how all these other GSIs fit together like this containment bypass thing? Is this question of risk assessment also have been covered in other work that's going on that we don't know about? Is it possible for you to do that?

DR. MUSCARA: With the GSIs?

CO-CHAIRMAN FORD: Well, I don't know if GSI's the word right word; other projects. You mentioned you had another project going on on containment bypass issues.

DR. MUSCARA: Right. No, this is part of the action plan.

CO-CHAIRMAN FORD: Okay.

DR. MUSCARA: And most of the work we are doing is in the action plan, including the understanding of the degradation.

But to respond to the question where

they come in; it really comes in through the PRA and the object of the PRA at this point is to evaluate the potential for containment bypass.

MEMBER RANSOM: Would it be possible to just briefly review what motivated this action plan in terms of either accident sequence or how it arose?

DR. MUSCARA: Well, there's an entire ACRS report where a number of issues were identified and where we were told that we were not doing a credible job in certain area. And one of them was in the PRA area.

MEMBER RANSOM: Was this because of severe accident concerns?

DR. MUSCARA: This is mostly in severe accident concerns, and at that time it was felt that the PRA structure that we had been using wasn't adequate nor were the data inputs. So a lot of this work is aimed at addressing the data inputs to improve the PRA.

MEMBER RANSOM: Any particular severe accident sequence or was it just generic, any severe accident?

DR. MUSCARA: That, of course, is part of what the PRA folks are doing to try to identify the scenarios of interest. The one we worked on mostly in the past has been the station blackout and with the dry secondary.

Well, besides the work that's in the actio plan, I wanted to mentioned this morning that we have conducted an integration effort for the steam generation research programs in the different divisions of the Office of Nuclear Regulatory Research.

This past summer, sometime between June and October, I held six one day meetings with the technical staff and the technical leads in the different areas of the steam generator work to essentially integrate all the work, to have a common knowledge and understanding of what the overall objective of the program was, and to develop a detailed plan that we could follow and make sure that the work gets done.

Maybe I should mention that for the technical leads in research for the various areas are Chris Boyd is the lead for the thermal hydraulics. We have Roy Wood who is the lead on the PRA. Jim Davis is the lead for the steam generator integrity work. And Joel Page is looking at the work on primary system component failures under severe accidents conditions.

In addition to the NRC staff we also have the benefit of working with during these six meeting with Dave Bradley from SAIC, who is our contractor and also Sandia, but Dave was nearby so he participated in our meetings and helped us get through --

CO-CHAIRMAN WALLIS: I'm sorry. The PRA is the whole. So you're saying essentially what we've said; the PRA integrates everything? So there must be an existing PRA which for some reason is defective and you're improving it? And have you found out what are the defects in the present PRA?

DR. MUSCARA: What I was talking about is integrating the work that's going on in research.

CO-CHAIRMAN WALLIS: You see, what happened was ACRS looked at your stuff and said gee, that doesn't look very good, that doesn't look very good there. And so you're responding to that. But the overall purpose is not that. It's really to improve a PRA. So someone really should begin. The PRA should stop first and you should say, look, that part of the PRA isn't good. We've got to fix that.

So I don't know what you're starting with as a PRA that isn't good enough that needs to be fixed.

DR. MUSCARA: The integration meetings started with the work we are doing, why we are doing it, how it fits together.

CO-CHAIRMAN WALLIS: But you see my problem? You're responding to pinpricks from the ACRS rather than the design purpose which is to make a better PRA.

DR. MUSCARA: Again, we're developing the building blocks so we can achieve that. And the work is ongoing. Unfortunately, it got started late, but it did get started this past year to improve the PRA.

CO-CHAIRMAN WALLIS: Okay. Well --

DR. MUSCARA: But the idea was that we needed to get together and decide all the work that we're doing, is it reasonable, does it fit somewhere, is it needed by the PRA? And we've done this. In effect, we identified a couple of areas which were not being addressed because we had not had the integrational meetings. So we did discover a few areas where we needed to incorporate and include--

CO-CHAIRMAN WALLIS: So let me ask you a specific question. The question that arose in my mind was you're trying to fix up the PRA. You have a PRA already before the work?

DR. MUSCARA: The staff had done a risk analysis --

CO-CHAIRMAN WALLIS: And for some reason it was not good enough --

DR. MUSCARA: That's right.

CO-CHAIRMAN WALLIS: -- to do certain things?

DR. MUSCARA: That's right. The ACRS, and I think even the staff concluded that that was not good enough, needed to do better.

CO-CHAIRMAN WALLIS: So you --

MEMBER KRESS: These sequences are basically evaluated in every PRA.

CO-CHAIRMAN WALLIS: So it would be fairly easy to say if we had a different time temperature thing to put it in the PRA, we know how it fits in there?

DR. MUSCARA: Well, I think we're taking advantage of the lessons learned from the PTS studies in the PRA. And we are going to try and use similar process that was used --

CO-CHAIRMAN WALLIS: So you know the places where it's sensitive to assumptions and so on, you know all that stuff because you've got a PRA?

MR. WOODS: Joe, can I help you here? Do you want to --

DR. MUSCARA: No, go ahead.

MR. WOODS: Roy Woods again.

Basically what we're doing, and this is restricted to the severe accident in this part, but that's the major place where we think PRA specialists can interact with this. Anyway, that's what we're doing now. We intend to broaden it later.

But we basically have obtained the PRA. We're evaluating what needs to be changed and added to it, what's insufficient, what's not completed and that's exactly what we're doing. We're trying to put these pieces together into a coherent model that would allow you to calculate the risk. And these gentlemen on my left have the details of that, but I'd be taking over Joe's meeting if I get into that right now. We have a presentation late tomorrow. But we'll respond to whatever questions or clarifications in the meantime if we an help.

CO-CHAIRMAN WALLIS: But this doesn't appear in, say, a CFD report. It doesn't sort of say the existing -- well, maybe it does and I missed it. The existing PRA does this, and it takes this input and so on. And because the phenomena are not well modeled, there is uncertainly about how this is related to that, therefore we need a better measure of this. And that's why we're doing the work. And we know when the work's finished because we've got what we were looking for. If that perspective were put on everyone of these things, maybe it would be clear.

MR. WOODS: That's what we're trying to do, is to put the uncertainties and the things that aren't included like some of the human actions, we're trying to see what the inadequacies are in an existing up to date PRA and develop a model that will really do this much better than what exists at the moment.

CO-CHAIRMAN WALLIS: Right. So I think -- we're not going to ask so many questions, I hope, from now on.

DR. MUSCARA: Oh, no. I hope you do. At least you're hitting on things --

CO-CHAIRMAN WALLIS: No, but I think it's good to establish some of these ground rules.

DR. MUSCARA: But the integration

meetings really had to do with we are doing work, why are we doing, where does it fit and how does it fit in getting to the final goal, which is having an improved PRA.

CO-CHAIRMAN FORD: Joe, I think this particular graph is very important in resolving Graham and my concerns. Because essentially what it's saying, if I read it correctly, is yes we are taking into account all these integration of these specific items already and the DPO program which we're just evaluating today are just pinpricks, as Graham says, in this overall program.

Now, it would be very, very interesting as far as helpful just to show as a flow diagram for each of these different programs, including the DPO program.

DR. MUSCARA: Unfortunately, I did not make a viewgraph --

CO-CHAIRMAN FORD: Oh, no. Tomorrow will be fine, Joe. It's just so that we know --

CO-CHAIRMAN WALLIS: Maybe at the end when you summarize you can show it --

DR. MUSCARA: Okay. It shows all the different things put together.

CO-CHAIRMAN WALLIS: But that's

milestones. That's not a logical.

DR. MUSCARA: Okay.

CO-CHAIRMAN FORD: And so that that we can look at that flow diagram and say, hey, this is where we've got the critical gaps in technology. Like you did the PTS, basically. Exactly.

MR. WOODS: The thing he held up, it's got 93 lines, 78 actual lines if you take out the blanks and it shows how all these pieces fit together, at least for the severe accident induced part of it. But we do not want to go into those 78 lines with the ACRS.

CO-CHAIRMAN FORD: No. I'm not suggesting that you should go into all of it.

MR. WOODS: But we have done it; that was what the six meetings were about.

CO-CHAIRMAN FORD: But that resolved, just by showing us that, immediately resolves our problem.

DR. MUSCARA: I'd be glad to. I avoided doing that because I thought if we started talking about this, we'd get bogged down for two days on just this.

CO-CHAIRMAN FORD: Sure.

DR. MUSCARA: And I want to have a

progress meeting, a technical meeting but let you know what the research results have been up to this point.

MR. WOODS: I think it would be more like two weeks.

DR. MUSCARA: But we'll make sure that you get this.

CO-CHAIRMAN WALLIS: So you know how the thermal hydraulic analysis of the steam generator fits into a prediction of the course of an accident? You know how Chris Boyd's work fits into a modified RELAP, or whatever it is that takes into account this new modeling?

DR. MUSCARA: Yes.

CO-CHAIRMAN WALLIS: You know that?

DR. MUSCARA: Hopefully, we will discuss that as the two days go on. But that was the objective of doing all this integration.

CO-CHAIRMAN WALLIS: Maybe we'll see that tomorrow then.

DR. MUSCARA: And maybe I shouldn't even get into example, but I thought since you had the questions of how things fitted together, I wanted to tell you we have developed this integrated plan. And as an example, the PRA may identify likely combination of events. Then the thermal hydraulic defines the time, temperature, pressure conditions that one obtains based on these events. That information is used by the steam generator tube integrity area by making use of flaw distributions, probably of flaw detection, using integrity models to evaluate the tube failure to burst and leak rates.

The same information is used for also evaluating the times to failure, water primary system components, just the feed back were based on these results, whether this leakage or burst is fed back into the thermal hydraulics into the PRA. And eventually we'll have to make use of information aerosol deposition to determine potential release of radioactivity. But this is just a very brief, a very simple example but I wanted to mention that we are integrating and taking a look at these areas to be used in the PRA. And, again, we're right now essentially putting together the building blocks.

MEMBER BONACA: Yes, I didn't participate in the DPO. I mean there are essentially -- I mean clearly the -- the barrier performance, those things the tubes provide both in accident analysis and in severe accidents. And if you start from that, I mean I think it's a pretty reasonably simple picture of how you propagate the needs to address, in fact, this barrier performance in both conditions.

DR. MUSCARA: Yes.

MEMBER BONACA: And I don't think it would be too complicated to derive almost, like, you know a statement from each one of them what pieces you need and then these things fall in place.

DR. MUSCARA: Yes. And fortunately we have done a lot of work in the past on evaluating integrity of steam generator tubes. Well, what's new in this integrated effort is the work we're doing on the primary system component figures. Because if those components would fail before the steam generator tubes --

MEMBER BONACA: Yes.

DR. MUSCARA: -- then that's a good situation for containment bypass.

MEMBER BONACA: Yes.

DR. MUSCARA: So we're spending a lot of time and attention also in coming up to speed and doing better analyses of the other time resistent components.

MEMBER BONACA: Yes, even though, I mean

you can address in the context of this issue. I mean, you know will in fact the steam generator tube provide that barrier of protection that you intend to have or would like to have during severe accidents or will some other component fail before that. And that's why you're going to look at some other component to determine that?

DR. MUSCARA: Right.

MEMBER BONACA: So I think the logic of the process you're following doesn't seem to be excessively complicated. I mean you could -- and hopefully it will come through in the presentations.

DR. MUSCARA: This integrated program, we're planning on having it finished by end of FY-05. Again, there will be some other activities going on, for example, study in degradation. But evaluation of the containment bypass potential will be done by the end of '05. And hopefully all the building blocks and all the bits and pieces that fit together will be done. And our integrated plan shows how those things are done, when and how they fit together.

And I think I probably have taken up more than the time you had allowed for me. And I think we can go ahead and get started with the technical presentation.

CO-CHAIRMAN FORD: Well, actually, we could put your final graph, five. Now you've got two years of work for the end of the fiscal year '05, and you've already heard murmurings, the question about the completeness of the thermal hydraulics inputs, completeness of the PRA inputs. Do you think as a technical guy this is doable by end of fiscal year '05?

DR. MUSCARA: Well, yes. That particularly why we had these six meetings with all the staff involved. And we, in fact, you know by doing this process we identified where the bottlenecks were. So we then studied very diligently whether the bottleneck could be improved. And so we reiterate a number of times, but the idea was what we need to do, can it be done and can it be done any sooner if the resources were there.

In fact, when we started out it was about another additional year on this. But then we found out by some combinations of tasks, some additional efforts, we were able to improve that schedule. And we feel quite comfortable that by the end of '05 we can --

CO-CHAIRMAN FORD: And the end metric in fiscal year '05 you'll have some sort of algorithm that says that the risk of radioactivity release is a function of, and then you have a whole lot of variables in PRA space for the uncertainties so you'll relate inputs to that?

DR. MUSCARA: We will develop the process and in addition we will run the process for a typical plant.

CO-CHAIRMAN FORD: Yes. Okay.

The very last bullet, now you said that the initial set of presentations for this meeting.

DR. MUSCARA: For this meeting, yes.

CO-CHAIRMAN FORD: And what I heard you say was that you've essentially addressed the concerns that were raised in the DPO associated with NDE, the concerns that were raised about the extension of a crack, a pre-existing deep flaw under the ⌂ps associated with an MSLB; that's been resolved? And the iodine spiking issue has been resolved?

DR. MUSCARA: Well, not resolved, but the idea is we'll give you presentations in these three areas.

CO-CHAIRMAN FORD: Okay.

DR. MUSCARA: Then as we're going

through the presentations, I've asked the staff and the contractors to identify which action plan item they're addressing.

CO-CHAIRMAN FORD: Right.

DR. MUSCARA: And when we look at the status in the action plan, we can see whether it's completed or closed, or not.

CO-CHAIRMAN FORD: Good.

DR. MUSCARA: But again, those areas where we see it's completed we also need to keep in mind that we might have completed it, but added additional work where we felt it necessary.

CO-CHAIRMAN FORD: Jolly good.

MEMBER SIEBER: Just to be clear the iodine spiking issue has been addressed but not resolved?

DR. MUSCARA: Correct.

MEMBER SIEBER: You just said we like the way it is.

DR. MUSCARA: Right. We'll give you a progress report, we are on that. I don't think you'll hear anything new on that issue, but I thought since it was an important issue of interest to the ACRS, that it should be on the agenda. And so it is on the agenda and you have the chance to comment.

MEMBER SIEBER: Well, that's right. Well, there is one page in the pack that you sent us that discusses. So when we get there, we'll discuss it.

CO-CHAIRMAN FORD: Before we leave this, before we let Joe off the hook, are all the members satisfied as to what the terms and conditions that we have as we go through this meeting, what we're being asked to do? I mean just so Joe knows up front as to--

CO-CHAIRMAN WALLIS: I'm not absolutely sure.

CO-CHAIRMAN FORD: Okay.

CO-CHAIRMAN WALLIS: I think we'll come around at the end and summarize and see where we are and what we have achieved.

MEMBER BONACA: I mean, I know that the action plan, it goes beyond the responses to the PPR

DR. MUSCARA: Yes.

MEMBER BONACA: Okay. But for the NUREG that we wrote, we did develop a discussion of those scenarios under accident analyses conditions and under severe conditions for which you had expectations on the tubes. And clearly I am confined to that kind of view still, because I see all these pieces and I'm thinking of those scenarios we questioned in that DPO. I don't think there is much more than outside of that. But maybe, you know, as you go through the presentation if there are some issues -- well, they may come up. They'll come up.

DR. MUSCARA: Yes, I didn't mention we're concentrating on the three point X items over the action plan. The action plan is broader, but those are the items that really result from the ACRS comments.

MEMBER BONACA: Yes.

DR. MUSCARA: On the DPO issue.

So, I think if we could move on, then we'll get going with the NDE and Dr. Kupperman from Argonne will do the presentation, the probability of flaw detection.

DR. KUPPERMAN: Good morning. I'm Dave Kupperman from Argonne National Lab. Bill Shack and I will be presenting the work on the steam generator eddy current NDE.

This NDE analysis round robin that I'll be discussing address the conclusions in the ACRS report that improvements can be made over the current use of a constant probability of detection for flaws. This round robin effort results in probability of detection as a function of flaw depth, voltage, location and m_p for 7/8 inch alloy 600 tubing. m_p is the stress magnification factor in the ligament.

In this presentation Bill and I will review the round robin and including discussion of the designs, fabrication of flaws, characterization, validation of depth sizing. And then I'll present the results of the round robin, which will be that POD is a function of these three parameters.

We'll also look at team-to-team variation of the POD. The round robin included 11 different teams analyzing exactly the same data.

This review will also discuss the nature of false cause and misses.

Other issues addressed are the bottom coil volt issue, the issue of signal-to-noise and finally a discussion on the array probe, the so called X-Probe as a potential advancement in eddy current NDE.

The objective then of this round robin effort is to evaluate and quantify the inspection reliability of the current methods being used for inservice inspection for the flaws of interest today. As I indicated, this will include the POD and also sizing accuracy. To validate the methods employed using both laboratory and field generated flaws.

On the left you see a photograph of the Argonne/NRC steam generator mock-up. It sits on a platform so that when we do inspect the tubes with the flaws in it, we simulate the more or less geometry of the actual inspection in the field.

To the right of the stand is a hut that contains the instrumentation and the computers, software, probe driving apparatus; all of which exactly reproduces that which is used in the field.

On the right you see a schematic of the mock-up. There are 400 tubes. Each tube contains nine test sections for a total of 3600 test sections. Over 300 of them have flaws in them.

The lower part is a simulation of tube sheet. These red lines indicate simulation of a drilled hole support plate and the remaining five levels are free span. And all of the levels have at least some flaws in them.

In this slide you see on the left a micrograph of one of the flaws that indicates that we can have rather complicated stress corrosion cracks in addition to rather simple ones, as might be indicated on the right through the dye penetrant indication of the log interest there.

All of the text sections that have OD flaws, OD cracks are evaluated with the dye penetrant

CO-CHAIRMAN FORD: Could I ask a general question here, and it's more for my interest? The fact that you've produced the cracks by nonprototypic environments and potentially different crack methodologies -- I mean, I'm fishing here. I don't know what the answer is.

CO-CHAIRMAN WALLIS: That's a good question.

CO-CHAIRMAN FORD: Has there been a qualification done of the type of cracks as to whether you're introducing a different flue phenomena or whatever it is in this crack? I know you must have addressed it.

DR. MUSCARA: Yes. I think all of us are eager to respond to that. It's in the presentation, so we could wait.

CO-CHAIRMAN FORD: Okay.

DR. MUSCARA: But realistically we have.

Now we made sure that the methodology of the cracks and the signal response is similar to what one sees in the field. And we did this through --

CO-CHAIRMAN FORD: So you have done --

DR. MUSCARA: -- metalographic studies and through an expert group. So we put together a task group to make sure that the procedures we were using are the same procedure being used in the field, that the documentation developed is the same documentation that a utility develops before an inspection, and to make sure that the signals likes just like the ones you see in the field.

I mean, there's a great variety of signals that you see in the field. And the conclusion was, yes, these things are typical. And I'm sure --

CO-CHAIRMAN FORD: And they'll come up later on?

DR. MUSCARA: Yes.

CO-CHAIRMAN FORD: It's an obvious question.

DR. KUPPERMAN: As Joe indicated, we had a task group to review that the signals are comparable to the field and that -- so on.

Although there are many cracks in the

mock-up that were created using a doped steam technique by Westinghouse, most of the stress corrosion cracks are carried out using the sodium tetrathionate at room temperature.

MR. SHACK: But again, the cracks are prototypic both in terms of the general morphology, that is we had situations where we have a signal plainer crack, we have a raise of cracks, we have ligament that cracks. The most important thing from here is, in fact, the eddy current response for the NDE portion. And as Dave will mention, we have people that review the signals from these that essentially kind of qualify the signals. So they're typically in both the morphology and the eddy current response.

Now, obviously, things like the crack growth rate, you know, have absolutely no relationship whatsoever to the real world. But the things that we're focusing on here are reasonably prototypic.

CO-CHAIRMAN FORD: I've got questions along the same line. These are OD cracks, presumably produced crevices.

DR. KUPPERMAN: Some are ID

CO-CHAIRMAN FORD: Okay.

DR. KUPPERMAN: The mock-up contains both.

CO-CHAIRMAN FORD: The amount of variability between the various steam generator designs and this tube support plate designs, the circumferential ones versus the quatrefoil, etcetera, designs, that doesn't introduce another variable, different environments, different tube support plate geometries? Is that a big variable that should be taken into account in this issue?

DR. MUSCARA: Yes, it does. We've addressed some of those. But we are concentrating on the drilled support plate.

CO-CHAIRMAN FORD: Yes.

DR. MUSCARA: But had we produced conditions that the support plate at the top of the tube sheet where we in effect simulated the fabrication of a tube in a tube sheet so the tube is very tightly --

CO-CHAIRMAN FORD: Yes.

DR. MUSCARA: -- in an insert. There is a roll transition. We varied the amount of the depth of the roll transition to simulate a number of different situations.

We have dents at the support plate.

Different levels of dents again so that it can simulate dents at different locations.

So there's a long history with this mock-up. It originally started with our first international program at PNL many years ago when we started to assemble this mock-up. And originally the idea was to use this mock-up for -- performance demonstration. Originally inspectors were going to take this on the sides, much like they have done with piping and IGSEC to have the inspectors demonstrate their capability. So this was with an inspection program that ran out of Region One for a number of years. That program is no longer in place. The NRC no longer goes out with mock-ups.

At that point then we decided to change the objective of this generator and then we used it for conducting research and to simulate typical generators and be able to evaluate the probability of flaw detection using the current techniques.

But in building these mock-ups we took all kinds of pains to make sure that we were producing the actual condition one sees in the field, including things like sludge and -- and copper and dents and roll transitions and so on.

CO-CHAIRMAN FORD: Thank you, Joe.

CO-CHAIRMAN WALLIS: Thank you for this figure. I hope you'll talk about it, because the report tells me nothing about this kind of thing.

Okay. Please describe this figure so I understand what's being done.

DR. KUPPERMAN: Well, the purpose of this figure is to indicate that there are two probes used in an inservice inspection. On the left is a computer representation of the so-called bobbin coal, which is essentially a screening probe. It runs very quickly through the steam generator tubing model, as I indicated here, nominally around 20 inches per second.

And I have a probe that I'll pass around. And it looks for -- this computer calculation is actually showing you the currents that are generated. But the main point is that as the --

CO-CHAIRMAN WALLIS: Tell me again, what's the input? Are the coils excited in some way?

DR. KUPPERMAN: Yes.

CO-CHAIRMAN WALLIS: What's its measure?

DR. KUPPERMAN: Excite currents in the tube --

CO-CHAIRMAN WALLIS: Does it measure so me impedance or --

DR. KUPPERMAN: And then you can change an impedance as it passes a defect.

CO-CHAIRMAN WALLIS: So okay.

DR. KUPPERMAN: And it's reflected in --

CO-CHAIRMAN WALLIS: So that the current that it's able to generate when it's given voltage is dependent on what it sees around it. So when we see things like current -- voltage and phase angel and so on, does that means you've got a certain current and you're looking at the voltage you need to drive it or something?

DR. KUPPERMAN: You're looking at the voltage. You unbalance the bridge and you see the voltage run --

CO-CHAIRMAN WALLIS: Your output is voltage and phase angel.

DR. KUPPERMAN: Right.

CO-CHAIRMAN WALLIS: So current and inputs, is that what it is?

DR. KUPPERMAN: Right.

CO-CHAIRMAN WALLIS: Well, that's great. Because the voltage of a tube didn't mean anything to me at all.

DR. KUPPERMAN: No. The voltage was related to a --

CO-CHAIRMAN WALLIS: Okay. So there's millions of miles of wiggles come out of this thing, right? Millions of wiggles come out of this thing. And it wasn't clear to me do the experts look at millions of miles of wiggles or does a computer tell you there's a funny wiggle here, you'd better look at it? There must be a computer that sorts the data and gives the experts something.

MEMBER SIEBER: Initially.

CO-CHAIRMAN WALLIS: Limited set to look at. They don't look at millions of miles of data.

MEMBER SIEBER: Initially, right?

DR. KUPPERMAN: They look at every inch of the tube.

CO-CHAIRMAN WALLIS: They look at everything? They look at all the wiggles?

DR. KUPPERMAN: Yes.

MR. SHACK: And if they blink they miss something.

CO-CHAIRMAN WALLIS: They look at an infinite number of figures like the ones on the left side.

DR. KUPPERMAN: Well, they don't have an

infinite -- it's a continuous trace and they're looking --

CO-CHAIRMAN WALLIS: Why do you have an expert? Why don't you just have a computer that says if we get something anomalous, we're going to make an analogous or this blah, blah, blah and we're going to decide if it's significant or not, and if it is how significant. Why do you need an expert at all?

DR. KUPPERMAN: When you see a signal it doesn't necessarily mean it's from a crack and that's the problem.

MR. SHACK: Right.

CO-CHAIRMAN WALLIS: Oh. And what happens when this goes through a tube sheet? Doesn't that change the impedance of everything?

DR. KUPPERMAN: We use a different probe for the tube sheet.

CO-CHAIRMAN WALLIS: Oh, you do? Okay. The one on the right is so called plus point and that's --

CO-CHAIRMAN WALLIS: This thing goes up the tube and the experts look at the wiggles and squiggles?

DR. KUPPERMAN: That's right.

MR. SHACK: And when it goes through a tube support plate it does -- you know, things do happen and people do process signals to try to --

CO-CHAIRMAN WALLIS: And there's a person looking after that, it's not a computer analyzing the data? That seems very strange to me, but I guess it's all right. It's like a colostomy, you know. Several doctors look at this and say, gee whiz, there's an anomaly here, we'd be investigate it.

DR. KUPPERMAN: It is an art.

CO-CHAIRMAN WALLIS: Okay. It's an art. Thank you. That seems very surprising to me. It seemed to me it ought to be computerized.

DR. KUPPERMAN: There is automated data analysis that is used as a secondary review of the data. But it's not --

CO-CHAIRMAN WALLIS: They actually manage to look at millions of miles of squiggles?

DR. KUPPERMAN: We have lots of inspectors looking at data.

CO-CHAIRMAN WALLIS: Okay. All right.

DR. MUSCARA: That's a good point. You see, that's one of the reasons why sometimes for us it's missed and shouldn't be missed because, you know, inattention.

CO-CHAIRMAN WALLIS: Wouldn't a computer be better? It doesn't get an attention span.

DR. MUSCARA: A lot of research work has been done in trying to use automated systems. It's been fairly successful in UT. There's work done in eddy currents also, but it's not something that's in practice. And the reason is that, you know, no two signals ever look alike so it's very difficult to come up with parameters.

CO-CHAIRMAN WALLIS: So what they do, they're looking at a screen, let's say. And it doesn't have to be on real time, but they've got a record. And they say now we're looking at this thing going up the tube. We see all these wiggles and squiggles. Gee, there's a big squiggle. We'd better like at that. It's like an EKG or something, something anomalous about this particular signal.

DR. MUSCARA: Yes.

CO-CHAIRMAN WALLIS: Very qualitative?

DR. MUSCARA: That goes on in the process of an inspection, that does go on.

CO-CHAIRMAN WALLIS: Yes. Okay.

DR. MUSCARA: There's five different inspectors, they look at the signals. And it goes up --

CO-CHAIRMAN WALLIS: If they blink? Okay. Okay.

DR. KUPPERMAN: The idea is that there are several people looking at -- there's two people initially looking at the same data and they could have a computer that would trip a further analysis.

CO-CHAIRMAN WALLIS: And this surface writing thing is kind of similar, only it goes along the surface instead of down the middle.

DR. KUPPERMAN: Yes. This is a probe that's typically used. There are three coils on it and it rides against the inner wall of the tube and it's rotating.

CO-CHAIRMAN WALLIS: And they rotate it? That's what the rpm means?

DR. KUPPERMAN: But it's slow. And it's used -- for the tube sheet this probe is used for 100 inspection of the tube sheet, so this is --

CO-CHAIRMAN WALLIS: But it can't go around the outside. It only goes around the inside?

DR. KUPPERMAN: Yes, it goes around the inside.

CO-CHAIRMAN WALLIS: Ah. So it doesn't go around the outside? So you can't look at the outside of the tube inside a tube sheet? You can't look at the outside of a tube at all?

DR. KUPPERMAN: You can only look at the outside of the tube through the penetration of the--

CO-CHAIRMAN WALLIS: Okay. So this rotating thing is more likely to look at the inside of a tube than the outside of the tube. You don't have a rotating pancake for the outside of the tube?

DR. KUPPERMAN: Well, there's three coils on here. One of them is a high frequency small coil that is used for the flaws that would be on the inner wall. And then there's a larger pancake coil that an penetrate through to the outside wall of the tube.

MR. SHACK: The probe always goes through the tube.

DR. KUPPERMAN: But the probe is always inside the tube.

MR. SHACK: You change some of the parameters so that you intend to pick up more signals from the ODs and the IDs.

CO-CHAIRMAN WALLIS: More stuff from the outside. Okay.

MR. SHACK: One of the things about this rotating probe is that perhaps isn't as quite as apparent here is that it's focusing on a very small area of the tube. And so you're measuring the impedance change over a very small localized area. The bobbin coil is integrating over the whole tube.

CO-CHAIRMAN WALLIS: Right.

MR. SHACK: And so you get different types of information from the tube. You get much more detailed information from the rotating pancake coil. The price you pay for that, of course, is you have to analyze.

CO-CHAIRMAN WALLIS: Right.

MR. SHACK: If you think you have miles going this way, just imagine rotating around the thing as you're doing the pitch. Yo know, you've got gazillions of miles as it screws through the thing.

CO-CHAIRMAN WALLIS: That's true as it screws around in the tube.

Okay. And it's able to see the outside of the tube about as well as the inside?

MR. SHACK: We'll come to that.

CO-CHAIRMAN WALLIS: Okay. Okay.

DR. KUPPERMAN: It's easier to see the flaws on the inside in general, unless --

MR. SHACK: But the basic physics gives

you the answer that you think you know, which is it's easier to see --

CO-CHAIRMAN WALLIS: All this jargon about over coils and spin coils and various words that I don't understand at all means --

MR. SHACK: He'll explain it.

CO-CHAIRMAN WALLIS: He's going to explain it? You're going to explain it? Thank you. Because it's not explained in the report.

DR. KUPPERMAN: We'll address these ideas.

CO-CHAIRMAN WALLIS: Okay.

DR. KUPPERMAN: It's all in the book.

CO-CHAIRMAN WALLIS: So they look at things like the next figure?

DR. KUPPERMAN: No, those are two different coils.

CO-CHAIRMAN WALLIS: No, but they have to look at -- look for hours at something like the figure on the right hand side which is wiggling around all over the place?

DR. KUPPERMAN: Twelve hour day and they work seven days a week.

CO-CHAIRMAN WALLIS: And then they see, gee, we'd better stop. Turn it back, let's look at that in more detail because it looks funny?

DR. KUPPERMAN: Yes. You're precisely right.

CO-CHAIRMAN WALLIS: Ah, a computer ought to do it much better.

DR. KUPPERMAN: The computer can tell you -- it's automated data, it can tell you that there is a signal of interest.

CO-CHAIRMAN WALLIS: Right. Do that first as a screen and then look at them.

DR. KUPPERMAN: But we still rely on the humans.

CO-CHAIRMAN WALLIS: Okay.

MR. SHACK: As a pattern recognition device, a human being is not bad.

DR. KUPPERMAN: The brain is really better than the computer.

CO-CHAIRMAN WALLIS: That's right. As long as the attention can be maintained for 12 hours.

DR. KUPPERMAN: And these people are trained very well.

CO-CHAIRMAN WALLIS: Right.

MEMBER BONACA: This always assumes that the defects are known so you can characterized this type of defect with this kind of trace, right?

DR. KUPPERMAN: If you have a history of a certain kind of flaw, you know the pattern and that's fine. But the problem arises when a new flaw is generated that you haven't seen before.

MEMBER BONACA: Yes. And then that would challenge their ability to interpret?

DR. KUPPERMAN: That's absolutely right. Or if it was a flaw that you thought could not appear in this location, you might not spend a lot of time at that location.

CO-CHAIRMAN FORD: Then could you just walk us through the --

DR. KUPPERMAN: Yes, I have a lot to review.

So basically what the analyst will do is look at this linear trace with -- it's the vertical component of a -- figure. And they'll looking for a jump in the signal. If they see it, then thy look at the Lissajous figure, which can give you some information. But what happens mainly is that you go to that point with this rotating point that I passed around, which generates a three dimension image of the anomaly. And even thought this is just am amplitude product, just plots the amplitude from the rotating coil, that plus point coil, it does gives you a general idea of what's going on. And through experience and through training and through validation procedures and testing they can get information also from the Lissajous figures to come to a conclusion --

CO-CHAIRMAN WALLIS: So the analogy with all kinds of medical instrumentation is very good. I mean, I'm more familiar with that than with this stuff. But very similar.

CO-CHAIRMAN FORD: But there is enough empirical information, presumably, to correlate those signals that you show in that little box on the right hand side to a physical phenomena such as, for instance, say surface region versus a cracked region, versus crude on the surface on the OD? I mean, there's enough empirical observation to make that judgment?

DR. KUPPERMAN: Well, there are certain rules that they follow. For example, how does the Lissajous figure rotate, does it change the frequency? Does it rotate counter clockwise or clockwise? That already tells me something.

CO-CHAIRMAN WALLIS: Do the frequencies vary throughout the experiment or he has a choice of changing it?

DR. KUPPERMAN: As you go deeper and deeper into the analysis of an indication, you vary the frequencies, see how the frequency changes.

CO-CHAIRMAN WALLIS: Well, you go back and do the experiment again?

DR. KUPPERMAN: The data is all collected.

CO-CHAIRMAN WALLIS: They just collected a response to frequencies. Ah.

DR. KUPPERMAN: It's all collected once. And then you go back and you say well these --

CO-CHAIRMAN WALLIS: So it's a signal which has a mix of frequencies in there?

DR. KUPPERMAN: Yes, you use four frequencies.

CO-CHAIRMAN WALLIS: Okay.

DR. KUPPERMAN: And you screen with one.

CO-CHAIRMAN FORD: So in other words, when it comes down to look at probability detection, you're looking at not only team tiredness, human errors plus uncertainties in the physical analysis of those wiggles --

MR. SHACK: That's correct.

CO-CHAIRMAN FORD: -- i.e., crack,

crude--

MR. SHACK: Geometry.

CO-CHAIRMAN FORD: You never know unless you do a direct examination. Okay.

DR. MUSCARA: Maybe I could comment very briefly, make sure that you don't have the wrong impression. Eddy current tests you do not really get the kind of detail that you were discussing. You can get fairly easily whether you're looking at a flaw that's volumetric, for example, corrosion, large patches of corrosion or whether it's crack like. But to break it down much finer, it's not quite possible.

By looking at the way the signal moves and the different planes you can tell whether it's ID or OD, etcetera. But to get down things like code work, mostly information we get from eddy current is really based on our experience we have with observation of particular location. So the inspectors depend a great deal on location and what they expect to see at that location.

As Dave mentioned, if it's something that's new for the first time, very often it's missed by the inspection. So, you know, you can tell it's ID or OD, is it volumetric, is not volumetric. And by knowing the location you assume it's a --

CO-CHAIRMAN WALLIS: You have to have a lot of experience.

DR. MUSCARA: Right.

CO-CHAIRMAN WALLIS: It's sort of like sonar in the submarine or something. Unless you've had a lot of experience, you don't know what it means at all.

CO-CHAIRMAN FORD: So in terms of ranking uncertainties, a big question will be is the crack circumferential or axial? Is the amount of information that we have to show it would indicate that the uncertainty in making that decision is very low?

DR. MUSCARA: Yes, it is. I mean, if you can detect the crack, you can determine if its circumferential or axial. Detecting it is another problem.

CO-CHAIRMAN FORD: Okay.

DR. KUPPERMAN: Most of the time you can determine if it's circumferential or axial. It's possible to have a series of small axial cracks going around the circumference that could look like a circumferential crack but a really good analyst could sort out the data and come to that conclusion.

CO-CHAIRMAN WALLIS: Okay. Could we ask about this really good analyst? Is this someone who has been trained for a week or is it someone who has had ten years of experience?

DR. KUPPERMAN: Years of experience, and then they have to pass qualifying examines to make--

CO-CHAIRMAN WALLIS: This is why, again, you got very small band of people who understand how to do this right?

DR. KUPPERMAN: They're very well trained.

MEMBER SIEBER: Well, you end up with a team. You have a level two guy --

DR. KUPPERMAN: There are five people that are involved in that, in looking at this data.

MEMBER SIEBER: And anything that's strange, the level one guy will look at, you know.

DR. KUPPERMAN: Somebody collects the data, and then more trained people analyze it.

MEMBER SIEBER: Yes.

CO-CHAIRMAN WALLIS: It's even more reason for having computers sort it out first so you -- you're relying on this. There's a huge amount of experience. You've got to have an expert with years of experience.

MEMBER SIEBER: They actually watch the probe move. The computer is looking at it and trying to characterize it. Somebody is watching it there. You know, it can't be --

CO-CHAIRMAN WALLIS: But it's a difference. I mean, they have ways of sort of observing. There's all this stuff, invasion of privacy where they're looking at what's happening in some area, as to something anomalous, like a terrorist appearing somewhere. And you have a guy looking at that screen all day and in case something anomalous appears; that's not the way to do it. You have to have a computer that looks -- gee, there's something I want to see. You go and look at it now in detail and see what it is. That's the only way to do it.

DR. MUSCARA: Well, that's been tried.

CO-CHAIRMAN WALLIS: Only way to do it.

DR. MUSCARA: You know Dave mentioned there is qualification performance demonstration requirements.

What has happened in some cases with the computerized system is that you miss flaws, and you miss them because the simple parameters that you can set up, for example, amplitude, is not always an indicator of a crack being present.

CO-CHAIRMAN WALLIS: Then it's not smart enough. It's not smart enough. But if the computer could be made as smart as an expert, because the expert is looking for the same specific things.

DR. MUSCARA: And maybe later on you'll hear about an algorithm we've been developing at Argonne --

CO-CHAIRMAN WALLIS: Yes, I noticed that.

DR. MUSCARA: -- that makes use of some of those kinds of things.

CO-CHAIRMAN WALLIS: Yes, it sounds good.

DR. MUSCARA: But it's now in the future.

CO-CHAIRMAN WALLIS: Sounds good.

DR. KUPPERMAN: Well continuing then --

CO-CHAIRMAN FORD: Joe, I'm just looking at -- this is really very interesting indeed. I'm just looking at the clock here.

CO-CHAIRMAN WALLIS: Yes.

CO-CHAIRMAN FORD: Do I understand that

we're going to get through not only this one, 3.6, but also 3.7 and 3.8 before the end of the morning?

DR. MUSCARA: Yes, I think you are correct. Right, by 12:15 we'll finish up. But I don't think there's a great deal of discussion on 3.7 and 3.8. Louise is here, and she'll be making that presentation. Is that right?

CO-CHAIRMAN WALLIS: What is 3.7 and 3.8 about?

CO-CHAIRMAN FORD: What were they about?

CO-CHAIRMAN WALLIS: Just remind me. This is the one where you threw away the French data?

DR. MUSCARA: Yes.

CO-CHAIRMAN WALLIS: Okay.

DR. MUSCARA: And I'm not too sure what 3.8 is about.

CO-CHAIRMAN WALLIS: IS it about the seven eighth inch tubing or something? Seemed to be somehow different from the --

CO-CHAIRMAN FORD: Yes, 3.7 is to do that. And 3.8 has to do with -- I'm not too sure. It's only a one page memo. I'm not to sure what it's saying. They're not going to take up a half hour of discussion.

CO-CHAIRMAN WALLIS: I think, Mr. Chairman, now we know what we're doing we might go pretty fast from now.

CO-CHAIRMAN FORD: Okay.

CO-CHAIRMAN WALLIS: Because it's not as if it gets very complicated later on. Specific outputs.

DR. KUPPERMAN: We're trying.

On this slide I want to point out that at Argonne we have developed a multi-parameter algorithm to improve on the characterization of flaws. And this algorithm uses the amplitude and phase information at several frequencies to provide both 2-D and 3-D flaw profiles.

So, for example, here's a representation of a flaw in a roll transition looking down on the flaw. And down here is the reconstruction of its profile. And the geometry can be subtracted out so we just see the flaw.

And the beauty of this is is that you get not just amplitude as a function of position, but you get the actual depth of the profile as a function of position. And you can cut through it and get slices --

CO-CHAIRMAN WALLIS: Now, an expert

couldn't generate that out of his head, just look at the -- that's much better than the expert.

DR. KUPPERMAN: Yes.

CO-CHAIRMAN WALLIS: Oh, good. Thank you.

CO-CHAIRMAN FORD: Could I ask Joe, this Argonne multi-parameter algorithm, is this used and approved generally within the nuclear fleet?

DR. MUSCARA: It is something we have been developing for a number of reasons. One is we needed to have an accurate method for characterizing the flaws in the mock-up because we can't destroy all of them. And so we have been working on this.

And the other one is, of course, that it's making improvements in the technology.

Now, we've been working on this for a number of years. You know, our program in general is an international program, so we have people from Korea and from Canada, and Westinghouse in the U.S. and EPRI; all these people have been interested in this algorithm. They've asked for them to have access to it so they can try on field data. So some of this has been going on. It's not something that's out there that's qualified yet, but there's an interest. People have looked at it and they're trying to see how they could use it.

Unfortunately right now, you know, it's not necessarily a computer friendly algorithm and you need an expert who really understands it to get best results. But there is, you know, some activities going on to try in making it more user friendly and being able to transfer the knowledge that needs to go into this to others.

CO-CHAIRMAN WALLIS: Well, this is where the action is in all imagining technology right across the boards using the computers. Because they can now do so many things better than experts if you know how to tell them what to look for.

DR. MUSCARA: Well, this is a combination. It's based on -- we're calling it an expert system. So it's based on the kinds of things that the experts does to evaluate the signals, which are them permetized and computerized.

CO-CHAIRMAN WALLIS: Right.

DR. MUSCARA: But you certainly do need to know how to set it up, etcetera, and that's the portion that's not field ready yet. But it has very good potential for being able to fully characterize degradation with respect to its length and depth and location.

CO-CHAIRMAN FORD: So as we go through this presentation, the probability of detection figures will come out of this are the best that you'll ever do and in fact on other plants which are using older techniques, below --

DR. MUSCARA: What we'll show you is the probability of detection with the currently used techniques as they are used in the field.

CO-CHAIRMAN FORD: Right.

DR. MUSCARA: This process -- procedure we're using to essentially it's a true state -- to develop the true state of the flaws. Eventually something like this could be commercialized.

CO-CHAIRMAN FORD: So the correlation function, if you like, between observed and assumed by calculation were much better for this than it will be for a commercial instrument?

DR. MUSCARA: Yes.

CO-CHAIRMAN FORD: And that will be taken into account in your conclusions?

DR. MUSCARA: Yes. I think Bill will cover how that is being used in developing those POD curves.

MR. SHACK: Yes. But the important thing is the POD curves you're going to see are for the current techniques that are used by industry. We use this technique only -- you know, you're going to see POD curve as a function of depth. Well, how do you know the depth of that crack? We know the depth of the crack because we did this to it.

We also had the advantage that we knew exactly where that crack was because we put the crack there.

You know, we knew lots of things about that crack that the poor inspector doesn't know.

CO-CHAIRMAN FORD: But this is the best you could ever do with the current state of technology?

MR. SHACK: We don't measure POD here. I mean, we don't need a probability of detection. We know there's a crack there.

CO-CHAIRMAN FORD: So you've got POD of what?

MR. SHACK: The POD you see is what the -- the actual field inspector using his techniques uses.

DR. KUPPERMAN: On the mock-up.

MR. SHACK: Now, again, we will discuss what you see on the mock-up is probably better that you can do in the field because: (1) you're under a tech -- well, I don't want to steal Dave's thunder. But the POD curves you see are not POD for this fancy PHD level technique. They're the work a day inspector's techniques.

CO-CHAIRMAN FORD: I'm with you.

DR. KUPPERMAN: Let me make a comment and maybe you can understand why this is so complicated.

Eddy current is a diffusion phenomenon. You can't back out what created the signal like you can in ultrasonic scattering where you can look at the scattered signal and recreate what was there to cause the scattering signal. This is a diffusion phenomenon and you cannot calculate what was there that created the signal. And that's why it comes down to pattern recognition application, and some people looking at it.

MEMBER RANSOM: What as the axis on the figure on the left?

DR. KUPPERMAN: You talking about this?

MEMBER RANSOM: Right. Are those frequencies?

DR. KUPPERMAN: I don't want to get into this. These are standards that are used to set this up. These are notches and this is going around the circumference. This is axial.

MEMBER RANSOM: Well, are those units length or --

DR. KUPPERMAN: Those are units. You can get the axial and circumferential position in millimeters or whatever. But those are not --

MR. SHACK: For the non-inspector person, the figure on the right is the one you want to look at. It sort of looks like cracks.

DR. KUPPERMAN: This is millimeters.

Now, in this round robin exercise we want to point out that --

CO-CHAIRMAN FORD: I can see you plagiarized from Italy.

DR. MUSCARA: Dave's not familiar, but Bill is.

MR. SHACK: Yes, we plagiarized from Italy. Geovana's round robin exists forever.

CO-CHAIRMAN FORD: Her's used to be in color, right?

MR. SHACK: No. This is scanned right from her sketch.

DR. KUPPERMAN: Let me go through the round robin in a little bit of detail.

First of all, the data that was

collected was collected by a team from industry that was qualified for collecting data and followed the current practices.

Eleven teams analyzed the data, two from South Korea and one from Canada. And all members of the team have had to pass qualification examines. So these are all qualified analysts.

CO-CHAIRMAN WALLIS: These are typical of teams who will be doing actual inspections on steam generators?

DR. KUPPERMAN: These are people --

CO-CHAIRMAN WALLIS: They have five people in their team?

DR. KUPPERMAN: -- that do analyses in the field. These are field analysts.

And each team consisted of five members. There's a primary and secondary analyst, two resolution analysts and a fifth qualified data analyst, which would resolve any disagreements.

CO-CHAIRMAN WALLIS: So there's nothing technically at all? It just deals with people?

DR. KUPPERMAN: Most of the time everybody agrees on everything, but not all the time. And, of course, the not all the time flaws are the ones that are causing misses sometimes.

So, in addition to that we had a task group make up of members of experts from industry; EPRI and then the various organizations I mention here. And they looked at our documentation. We followed all of the procedures that are involved in an inservice inspection. There's a lot of documentation that has to be put together, guidelines, assessment of the degradation that they're supposed to be looking at. There's a training manual --

CO-CHAIRMAN WALLIS: I'm sorry. I think I was being flippant there. Really, the qualified -- really it's like the senior guy in the emergency room. The other guys that process the patient and say we think this guy has something or other, it's so bad we'd better bring in this senior to resolve something and figure out what's really going on. So the really qualified data analyst is the guy who has the most experience and knowledge, wisdom but doesn't have to look at the screen all day?

DR. KUPPERMAN: No.

DR. MUSCARA: Practically, as Dave mentioned, there are five members of the team. There's a level one and two, which have certain training but they're the lowest level. But there's also levels two and three who are the next step. But the qualified data analyst only gets involved rarely.

CO-CHAIRMAN WALLIS: The buck stops there, right?

DR. MUSCARA: Yes, but he's usually not necessarily the best qualified person. He's usually the person who works for the utility that has qualifications.

CO-CHAIRMAN WALLIS: Oh.

DR. MUSCARA: And he may turn out to be the best person, maybe not to be the best technically qualified person for eddy current.

DR. KUPPERMAN: I think the analogy is the QDA is the guy when they can't decide if the patient needs a heart bypass operation or not, he'll come in and resolve the issue.

CO-CHAIRMAN WALLIS: Especially if he is the best qualified, otherwise you may have sort of four technical people arguing and a lawyer trying to decide who is right. It may be the worst way to make a technical decision.

MR. KARWOSKI: This is Ken Karwoski from the NRR staff.

When plants analyze eddy current date,

people who actually analyze the data, even the primary and secondary analysts are considered qualified data analysts. And they analyze the date independently. Whatever calls they make go to what's termed a resolution analyst. All these people in this process are considered qualified data analysts or QDAs. And they follow an EPRI qualification process.

And so everybody who is analyzing this data as QDAs, the people on the resolution teams and on some of these senior review panels have reviewed the calls by the primary and secondary analysts are more senior, but all the people in this process are considered qualified data analysts.

CO-CHAIRMAN FORD: Thank you.

MR. SHACK: They're qualified by tests.

DR. KUPPERMAN: They're qualified by examines through EPRI.

So continuing on then, the task group looked at our documentation and looked at our flaws and concluded that we were following current industry practice and that the flaws in the mock-up had eddy current signals similar to those observed under field conditions. To the extent that it often looked at a flaw, a signal in the mock-up and say this looked -- and they would remember some indication in a plant somewhere; oh, yes, that looks like a flaw I remember from someplace.

So the -- first the teams look at the bottom coil data and then they look at the MRPC, the rotating coil for those test sections that would have indication that would require further analysis.

All of the analysts analyze the same data. The data is copied onto optical disks. They're brought to the location where the analyses is carried out. Argonne provides a proctor. And then their reports are taken back to Argonne and reviewed and analyzed and from which we established the POD using logistic fits to the raw data. And we end up with POD. And Bill is going onto how these curves are created in more detail.

But basically you get a POD curve as a function of crack depth, voltage and m_p with confidence limits that reflect the errors in the reference state.

CO-CHAIRMAN FORD: Now what was m_p? What is m_p? Sorry.

DR. KUPPERMAN: m_p is the stress magnification factor in a ligament.

CO-CHAIRMAN WALLIS: That's the thing

with the square root dimension and stuff.

DR. MUSCARA: It depends on the geometry of the tube.

DR. KUPPERMAN: I just want to show just an example of a field Lissajour figure and an Argonne LODSCC figure, and these two are the same. And then the amplitude plots for the same.

CO-CHAIRMAN WALLIS: It shows that they look very similar.

DR. KUPPERMAN: Very similar.

Also, we just took a look at -- you know, when we have a flaw in the bottom coil phase and both it should follow a general trend. We see that generally speaking the higher voltage is associated with lower phase angels as it would be in the field.

DR. MUSCARA: But the key point of the graph is that the McGuire sample will essentially trip out of the operating plant. And those were compared to the samples from the lab.

DR. KUPPERMAN: That's right. This was a retired steam generator.

DR. MUSCARA: You can see that they follow about the same trend.

DR. KUPPERMAN: So to characterize the

flaws. First of all, as I indicated before, we do have dye penetrant indications for all the OD flaws. And we've destroyed some of the mock-up specimens to help validate the sizing technique because we use --

CO-CHAIRMAN WALLIS: You use the penetrant after you've done the electrical measurement?

DR. KUPPERMAN: Pardon?

CO-CHAIRMAN WALLIS: You put the dye in after the eddy current experiment?

DR. KUPPERMAN: Oh before.

CO-CHAIRMAN WALLIS: Doesn't the dye effect the --

DR. KUPPERMAN: No.

CO-CHAIRMAN WALLIS: The dye and the space are the same?

DR. KUPPERMAN: We checked that. It doesn't effect the signal.

For most of the flaws, because we can't destroy all of them, we used a multi-parameter algorithm, and that's through blind testing we've established the uncertainty in that measurement.

CO-CHAIRMAN FORD: Do you mind just going back to the previous one, thirteen. What is that telling us?

DR. KUPPERMAN: Well, we just wanted to make sure that generally speaking if you have a high voltage, you are going to have a low phasing.

CO-CHAIRMAN FORD: Okay.

DR. KUPPERMAN: That's an indication --

CO-CHAIRMAN FORD: Regardless of the depth?

DR. KUPPERMAN: Not regardless.

MR. SHACK: Basically it relates to the depth.

DR. KUPPERMAN: But there's a general trend that doesn't really correlate to the depth. But we don't want to find out that most of our -- if we found out that most of our bottom coil voltages that are high were associated with a very large phasing, we would have a problem.

MR. SHACK: If we found our data following a 45 degree line, while this curve is going this way, that wouldn't be good.

CO-CHAIRMAN FORD: Maybe because --

MR. SHACK: They'd look different. Right.

DR. KUPPERMAN: This is just another way to help us to convince ourselves --

CO-CHAIRMAN FORD: You're looking at the

same physical --

DR. KUPPERMAN: The view of that, we are in the same -- I guess.

DR. MUSCARA: Steam verses lab test, that is the key.

CO-CHAIRMAN WALLIS: When the voltage is zero, the phase angel was random.

MR. SHACK: It's sort of anything you want.

DR. KUPPERMAN: Yes. You pick it.

CO-CHAIRMAN WALLIS: Pretty random, but it should be --

DR. KUPPERMAN: Yes.

Now, you might say well can't you just correlate the bottom coil voltage to depth? Why doesn't that work? And it doesn't. And there's just too many variables involved in the bottom coil volt that comes from an anomaly.

CO-CHAIRMAN WALLIS: Even with a 100 percent depth you get a very small voltage sometimes?

DR. KUPPERMAN: Yes, sir.

So these are the flaws that we destroyed so that we have accurate depth measurements on voltages. And this isn't a revelation. I'm just showing you as an example that this is the case.

MR. SHACK: It's a reminder.

DR. KUPPERMAN: The bottom coil voltage does not correlate with depth.

DR. MUSCARA: I don't want to delay the meeting, but maybe if you can state in a few words why in some cases this might not help. You know, the signal that you get is essentially is a back EMF from the test. Now, for you to get back EMF the current has to travel.

So if you have a notch that's nicely separated, the eddy current has to travel to the end of the notch to get through the material. So that provides a large back EMF.

What happens in the cracks is that the notches they're tight, they touch and they have ligaments. So you could have a crack that defectively from a structural point of view may be two inches long but has a ligaments. So as long as the electrons can travels through the small ligaments, the currents go straight through and provided a small signal. Therefore, you can get a crack that's critical size or one that's small giving you a low voltage. A big crack doesn't give you always big voltage unless it's separated.

CO-CHAIRMAN WALLIS: But did the crack make a difference or is the impedance of any cracks sort of infinite in the crack itself? Doesn't it go through -- a narrow crack which is so small --

DR. MUSCARA: Yes, that's what I'm talking about. If it's very tight --

CO-CHAIRMAN WALLIS: It goes back to the question when is a crack a crack?

DR. MUSCARA: Well, it's so small --

CO-CHAIRMAN WALLIS: I mean it may not have any impedance at all.

DR. MUSCARA: But that's the key problem, is that the currents can couple through the ligaments or the faces are touching. If there's a nonconductive crack that's conducted, the crack faces are clean, the signal goes through, doesn't go around the crack providing that signal.

MEMBER BONACA: And you would find, just for example, next year when you do again, will find suddenly --

DR. MUSCARA: That's right. Sometimes you see large changes in voltage. Well, maybe the ligament has finally broke.

MEMBER BONACA: Go back to the --

DR. MUSCARA: You know, we do find in

our samples sometimes we have very large cracks with very small signal response. And I think this is understood by the community.

CO-CHAIRMAN WALLIS: This is like ground water flow and cracked rocks.

MEMBER SIEBER: An analogy is the angle is the depth and the voltage from the -- the voltage is the electrical link from the crack which may be different than the physical length of the crack. That's generally the way I see it.

DR. MUSCARA: The voltage relates very nicely to volume that's missing.

MEMBER SIEBER: That's right. In fact, that's why they use eddy current probes for waste --

DR. MUSCARA: Yes, it works very well on that kind of flaw.

MEMBER SIEBER: But when you go through a tube support plate, everything just goes wild. So you have to reexamine those most of the time.

DR. KUPPERMAN: If you had a series of matches that were all one centimeter long, the voltage would correlate with depth very nicely. In fact, that's how you set up --

CO-CHAIRMAN WALLIS: Actually, I think you can go through all these details but the only real question and what really matters here is did the guys detect a crack or not?

DR. KUPPERMAN: We're getting to that.

CO-CHAIRMAN WALLIS: You spent a lot of time on these, whether this profile and this profile will come out the same.

MR. SHACK: Well, if you're willing to believe our curves, we'll skip directly to them.

CO-CHAIRMAN WALLIS: No, no. I was just wondering just exactly is there anything to do with how well the guys detect the crack?

MR. SHACK: No, but they have everything to do with as whether our curves are meaningful or not.

CO-CHAIRMAN WALLIS: Oh. Yes. Okay.

MR. SHACK: If you're willing to believe, we're willing to tell you.

CO-CHAIRMAN WALLIS: This is now the Argonne algorithm --

DR. KUPPERMAN: Yes. Now we're getting to the meat of it.

CO-CHAIRMAN WALLIS: But is this what the round robin people look at or is this --

DR. KUPPERMAN: No. We want to show you the accuracy that we have in knowing the --

DR. MUSCARA: Let me try quickly. We're trying to grade the inspector. And the way we grade him is to say he's detected a flaw and what size was it, or did he detect the large flaws, the small flaws? So we have to know what size flaws we have in the samples; the numbers and sizes. And unless we know the size, we can't really evaluate him.

CO-CHAIRMAN WALLIS: So you're using the PHD method to figure out what the crack really is?

DR. MUSCARA: We're qualifying him.

CO-CHAIRMAN WALLIS: I don't understand why they don't use the PHD method everywhere and everyplace.

DR. MUSCARA: Well, we'll try. We takes time for this to get outside.

CO-CHAIRMAN FORD: Could you go back to the previous one? Convince me so far the voltage means nothing in terms of -- you're showing two graphs now and saying that there's no correlation between voltage and --

DR. KUPPERMAN: I would phrase it as the correlation is very poor.

CO-CHAIRMAN FORD: Yes.

DR. KUPPERMAN: And it's also when we look at the field data we find the --

CO-CHAIRMAN WALLIS: But the Argonne method is very good. And there's a lot of stuff in your report. Many figures, like figure 17 showing that Argonne method is great. And I think I we're learning to accept it's great.

CO-CHAIRMAN FORD: And what was your point about the -- your -- this is something there was that changed? You got probably of leakage versus volts.

MR. SHACK: We tried to make it clear

CO-CHAIRMAN FORD: Oh, I see.

CO-CHAIRMAN WALLIS: That's what makes it difficult to figure out. What's the volts?

CO-CHAIRMAN FORD: Okay. Do you want to go through an explanation of that second bullet there, probability of leakage? Is this important to our understanding?

CO-CHAIRMAN WALLIS: I don't know that we need to.

DR. KUPPERMAN: Well, we have some flaws from McGuire that under pressure leaked. And we just point out that our results for leakage versus volts are consistent with what is out there in the industry.

MR. SHACK: They have 48 data points, I

believe, to develop a correlation for probability of leakage versus voltage. Our points would not change that correlation. And, in fact, if anything it would -- you know, since we didn't get any leakage, you know, it only is going to shift the curve to the right if we added our data points to their data points. But basically when they predict a low probability of leakage, we're not finding leakage. The only crack that we would have expect -- we have about a 50/50 chance of seeing leakage for the high voltage crack.

CO-CHAIRMAN FORD: Okay. So carry on.

MEMBER KRESS: This has to do with the voltage based --

MR. SHACK: The voltage based criterion.

MEMBER KRESS: Which I recall was good for some tubes and seemed to be weird for other sized tubes?

MR. SHACK: Better and worse, yes.

MEMBER KRESS: Okay.

MR. SHACK: Or worse and worse.

CO-CHAIRMAN WALLIS: But you just said there's no correlation between and voltage?

DR. MUSCARA: And the reason is because of lack of a physical basis for that correlation.

So we can't make that correlation any better. It is what it is.

DR. KUPPERMAN: Well, this is an example of how well the multi-parameter algorithm can profile a crack. And the blue is the result of applying the algorithm and the red is a result of the profile generated by fractography. So sometimes it can be very good.

It's not always this great, but we have the uncertainties developed as a result of looking at many, many flaws.

CO-CHAIRMAN FORD: Now just very briefly, there's not obviously just voltage, it's -- the voltage parameter.

DR. KUPPERMAN: This is --

CO-CHAIRMAN FORD: Phase angle, the frequency?

DR. KUPPERMAN: Voltage and phase at different frequencies plus rules. There are certain rules that are applied to the data.

So in this slide we point out that if using this Argonne multi-parameter algorithm sometimes when the cracks are simple, you got a very good correlation between depth and predicted depth and actual. But then when you get to more complicated flaws, there's some scattering of data.

CO-CHAIRMAN WALLIS: Well, there are sorts of ligaments. I mean, what's the depth?

DR. KUPPERMAN: The depth is the maximum depth.

CO-CHAIRMAN WALLIS: The maximum depth. But the --

MR. SHACK: Well, we profile the cracks sometimes and sometimes we use max depth so that the depth can be one or the other.

DR. KUPPERMAN: When you see the PLD curves there, it's maximum depth.

MR. SHACK: Yes, I can take over at this point.

Bill is now going to take over.

MR. SHACK: Okay. We just sort of want to talk about the determination of the POD curves and what do you get out of the round robin. Well, you have 11 teams that go through and they look at this crack and, you know, eight out of the 11 teams will find the crack and three won't. And so we get sort of ones and zeros are the results. We don't get continuous data. We get a binary result.

The probability of detection that we've discussed depends on many variables; crack length and depth, the orientation, the morphology, do we have a single plane or crack or many of them, the material grain and degree of cold work interferes with the signal, do we have artifacts like the roll transition or the tube support plate itself. We have other ones like dents, magnetite type, copper deposits.

We can't analyze all of these things. We don't have a model that incorporates all of these into a single picture. And what's done, and what's done in the industry, is that we try to deal with this by considering the data for a fairly specific procedure, a specific way of doing it and specific locations. And so you'll see POD curves for OD at the TSP, POD curves for OD cracks at the tube support plate. So rather than trying to build all that geometry and variations into the models, we just use different correlations. And in fact, in industry they will come in with even more specialized correlations that apply only to specific things. So they're trying to eliminate as many of the variables as they can.

So the only variable that we -- we typically concentrate on one variable at a time for a specific location, and that one that's most commonly used is the maximum depth.

MEMBER KRESS: And you can only do this if your specimens you used to develop the POD are assumed to be typical of what's out there.

MR. SHACK: Right. A representative.

MEMBER KRESS: Representative of what's out there?

MR. SHACK: Right.

MEMBER KRESS: Because it's going to have all those variables in it?

MR. SHACK: Because it's going to have all those variables in it.

DR. MUSCARA: Just one more simple point is that these techniques have qualified in industry. They're qualified for a specific probe and procedure and location.

MEMBER KRESS: Okay.

DR. MUSCARA: So it's broken down into fairly defined situations. And we've conducted the POD work for those probes, techniques and locations and types of flaws the way it was qualified.

MR. SHACK: So we'll typically -- I say "we," the only one that we consider here explicitly is crack depth -- I mean maximum depth. Actually, we do maximum depth, we do voltage because it's reported that way sometimes for the TSP. An we use this m_p parameter that we've discussed, which is the stress magnification. It, in many ways, is the most meaningful one because it incorporates the whole crack profile. So it incorporates the crack length. It tells you whether the crack has got a maximum depth that's uniform over a fair amount or it's just got a slight deep point and it's fairly shallow. And so it really reflects much more clearly the structural impact of the crack.

But the usual way of reporting data is primarily in terms of max depth, and that's what we've done most of the time.

Now, I've mentioned detection data are binomial, we get ones and zeros. If we try to fit data by -- you know, you don't use linear squares discretion when you're trying to fit binomial data. It doesn't make sense. We use essentially maximum likelihood estimates to choose the parameters to fit the data.

Again, we pretend that the probability of detection is really a binomial probability. Again, it depends on all these variables, but we've localized them by looking at the probability of detection for OD cracks at the tube support plate.

And so we're going to assume that our probability of detection depends only on crack depth.

CO-CHAIRMAN WALLIS: I think that -- I don't know. Maybe we should talk about this off the record. It seems to me that there's a correlation. If a team is bad, then it's not -- it's response isn't random for each one, it's got sort of a bias to being bad on everything it does. Is that reflected --

MR. SHACK: No, that's not true.

CO-CHAIRMAN WALLIS: It's not.

MR. SHACK: We'll come to that. But we do see variations between -- but unlike -- you know 20 years ago when Joe did some UT round robbins you found that. You know, there was the super team.

CO-CHAIRMAN WALLIS: Right.

MR. SHACK: And then, you know, there were other people. But we didn't really see that in this case.

CO-CHAIRMAN WALLIS: So you've got sort of five statistically identical teams or something.

DR. MUSCARA: It's because there's been a lot more training. I mean, both UT and eddy current there's training and qualification.

CO-CHAIRMAN WALLIS: Okay. So there's

more experience at interpreting data. Yes.

MR. SHACK: But that is one of the modern qualification thing is that we seem to have smeared out much of this variability.

CO-CHAIRMAN WALLIS: So they all have the same probability profile?

MR. SHACK: To the extent that we can tell from what we have. We don't see a real distinction.

CO-CHAIRMAN WALLIS: That changes the way you deal with the statistics.

MR. SHACK: And, again, so I can construct a likelihood function for this and --

CO-CHAIRMAN FORD: Bill, before you go on with that, can you just go back. Sorry. The very first bullet, you say "detection data are binomial." Detection by commercial methods?

MR. SHACK: Yes. This is the commercial team now. That's what we're trying to evaluate.

CO-CHAIRMAN FORD: And the commercial team --

MR. SHACK: And the commercial either says there is a defect there or that he misses the defect.

CO-CHAIRMAN FORD: Using voltage as the

sole --

MR. SHACK: Well, no, no. He's using his pattern recognition scheme to do that. Voltage is certainly one thing he's looking for. That's the thing that triggers him to look. But basically he has to look at this signal and look at the way the signal is behaving and make decision whether this --

CO-CHAIRMAN FORD: But if as you showed just previous voltage per se as a trigger point is not a good physical --

MR. SHACK: No, no. We said it didn't correlate well with depth.

CO-CHAIRMAN FORD: Yes.

DR. KUPPERMAN: It's possible that you'll miss a flaw because there is no voltage large enough over the --

MR. SHACK: Yes. And you know, voltage isn't a good measure. But if you have no signal, I guarantee you're not going to any analyze any pattern. So it's a necessary but not sufficient condition for --

CO-CHAIRMAN WALLIS: I mean there are always flaws there.

MR. SHACK: Right.

CO-CHAIRMAN WALLIS: And you could say

every time you get any wiggle at all, we'll call it a flaw.

DR. KUPPERMAN: Above a certain pressure.

CO-CHAIRMAN WALLIS: Yes, but that makes the different, doesn't it?

MR. SHACK: Right.

CO-CHAIRMAN WALLIS: So just detection of one or zero is --

MR. SHACK: No, but his result is a one or a zero. He either finds -- you know, whether he's doing it with a weegee board or an eddy current probe he's either find detected or not detected.

CO-CHAIRMAN WALLIS: That must depend on how familiarized he is before he --

DR. MUSCARA: It's the way we grade him. You know, he has a set of samples. We know there are flaws in there, and he either detected or not.

CO-CHAIRMAN WALLIS: You also know that there's a bigger probability that there being lots of little flaws than the big ones?

DR. MUSCARA: Oh, sure.

CO-CHAIRMAN WALLIS: So if he's more sensitive in his detection, he's going to pick up a lot more flaws, isn't he?

MR. SHACK: He'll have a very high POD.

CO-CHAIRMAN WALLIS: Yes.

MR. SHACK: And he could have a high POD even at shallow depths of he's very good.

CO-CHAIRMAN WALLIS: Yes.

MR. SHACK: We'll see how that works out.

DR. MUSCARA: But the point again, Peter, is that we're grading him based on the qualified procedure which set out -- it's written and they've been tested on their procedure. The procedure indicates what size probed, what kind of probe, what the frequencies are; all the essential parameters. So whatever the man does to qualify and he used in the field, is what is done on these set of samples. And he either detected or not. I mean, and it's not just necessarily voltage. It depends on the location, the type of -- etcetera. But it according to the procedure that he uses in the field that's been qualified.

DR. KUPPERMAN: In the analyst report the resolution analyses, the final report that we look at, for each test section there is a three letter code. And NDD is no detectable degradation or it'll be something else.

CO-CHAIRMAN WALLIS: So it seems to me you might get a mistake where one observer -- essentially one for all cracks above a certain depth and then falls off.

DR. KUPPERMAN: Right.

CO-CHAIRMAN WALLIS: You know, that's what you'd expect to find. And different people will fall off at different places?

DR. KUPPERMAN: Exactly.

MR. SHACK: And different locations that fall off occurs at different depths because some locations are more difficult than others, right.

CO-CHAIRMAN WALLIS: Are harder to see?

MR. SHACK: And again, this comes down to okay, now we're going to fit curve. You know, what curve are we going to fit? The curve we happen to pick is the so-called linea logistic . It's very related to essentially the cumulative distribution function for the normal distribution. And, you know, why would you do this? Well, I'm going to really demonstrate that it's mostly because we can fit any kind of a curve we want with it that seems reasonable, but a semi-physical argument that I'll bring up because I'm going to use it again later, and that says that our signal amplitude is generally related to the size of the defect in some way. You know, it's not a perfect correlation, but it's correlated in some way.

The responses we get from these depths have a distribution which we'll assume, will be normally distributed. And so I say a crack depth of .9, we won't always get the same response, but we'll get some range of responses that we'll assume is normally distributed if we had a whole bunch of .9 depths.

And we'll assume that the POD is the probability that this response we get exceeds the noise. Now, again, this is all kind of picturing the signal as being a voltage, and it's a little bit of a fudge to apply it to a pattern recognition scheme, but we choose as we usually do. So, you know, it's a reasonable form to pick.

Now, again, perhaps the best argument is that we can represent just about any kind of a POD curve that you expect to get. We might say that this would be the typical POD curve. Again, high probability of detection for deep cracks, for big cracks; low probabilities of detection for very shallow cracks.

We can get cracks where we have higher

probabilities of detection, but we get false calls. He think he's calling everything that might be a crack a crack. So he ends up essentially calling things cracks that aren't cracks.

CO-CHAIRMAN WALLIS: You're integrating is you're actually saying it's cracks above a certain size that you're looking at, a percentile type thing, a cumulative probability rather than a error function thing --

MR. SHACK: No, no. It's a cumulative function but you're actually looking at the binomial probability at a given depth.

CO-CHAIRMAN WALLIS: I know. I understand. I understand that.

MR. SHACK: It's a constrained sort of thing.

CO-CHAIRMAN WALLIS: Yes.

MR. SHACK: And again, the perfect POD is where he doesn't call any zero depth cracks cracks, but as soon as the crack has a little bit of depth he's up here at one and he just goes -- you know, so it's basically a step function.

CO-CHAIRMAN WALLIS: He's counting zillions of them when they're very small?

MR. SHACK: But he's finding everything.

So it's very good from a POD point of view. And as long as he's not making false calls, then he could then tell you something about the size, this would be wonderful.

The case, of course, is when he can't see anything until the crack is through wall, and even then he has a poor probability of doing it. And then you might have the difficult situation where you can't see anything but very large cracks.

And so, again, we can represent all of these.

CO-CHAIRMAN WALLIS: But what matters is that you detect the cracks that you care about?

MR. SHACK: Right.

DR. KUPPERMAN: Exactly.

MR. SHACK: Again, I won't go through the math of the maximum likelihood estimates. It's there.

We get uncertainties in these parameters for two reasons. One, you know we have binomials probabilities but we have relative small samples. And so we have uncertainties in our binomial probabilities because of the smallness of the sample.

We also have additional uncertainties

because we pretend we know the depth of the crack and we really don't. We have an estimate from our PHD level multi-parameter technique, and it's good, but it's not perfect. And it turns out that we have to account for those errors because of the smallness of the sample and the errors that we're making in the depth.

And again, we've been through this before, we've benchmarked the PHD technique against the destructive analyses.

We also do a sensitivity analyses where we look at forms at the POD curves other than this linear logistic normal distribution kind of curve that we pick. And the one that's sort of good is this log-log length where instead of having the log of the probability be linear, we make it expediential with depth. And I'd sort of argue that these are kind of bounding the ranges of responses we might expect to get. That you get a one where it sort of gradually goes up, the other where it goes up like -- very, very rapidly.

It turns out in industry they use a third one where they have a logarithmic dependence on it. This, in fact, gives you singular behavior at zero. So you're probability of detection really goes up in a singular way as the crack is non-zero. It turns out that this is not really different than the others. You know, when you have a behavior like that, obviously what do you do with the false call rate? Well, if you say that the false call rate you measure really applies to all cracks, say, up to 15 percent deep because you can't detect any of those anyway, you'll get something that looks like our linear logistic. If you say that it applies to cracks that are only very, very shallow so it's .1 percent depth, then it looks like my expediential type growth.

And so the two I've picked, I think I can argue sort of do bound the ranges of behavior that we would expect.

If I apply them overall, what I find is that in fact the expediential growth gives me slightly better statistical fits to the data. However, we decided to go with the linear logistic because in our expert judgment we just felt that it was unrealistic to have the rapid increase in the probability of detection for these low cracks. And so we've chosen to go with the linear logistic even though it may not necessarily give us the best statistical fit.

CO-CHAIRMAN FORD: Could you go back? You're really stretching me here, Bill.

In simple term tell me why these logistic approaches give a more physically realistic result?

MR. SHACK: Mostly because when you look at a crack that's 50 percent through, well he says there's no way that you have a 25 percent chance of finding this thing. It's a very small probability. So we think that curve starts very -- fairly shallow at the shallow depths and then begins to steeply rise.

CO-CHAIRMAN FORD: And I didn't listen until you got some data there. Those circles?

MR. SHACK: Yes. Those are zeros are ones, right.

CO-CHAIRMAN FORD: And just because the blue curve approximates more to the --

THE COURT: Well, you know, you want to do a least square fit in your mind, and it's not the right way to do it. It's hard for your brain to do a maximum likelihood estimate of a binomial probability. So you're used to seeing least squares that your brain works that way, but it's not what you're looking for.

MEMBER KRESS: But the curves are a maximum likelihood --

MR. SHACK: Yes.

MEMBER KRESS: -- fit to that data is what you're saying?

MR. SHACK: Yes.

DR. MUSCARA: Can I also mention in the same area, many years ago we did work similar to this for UT. We also looked at similar work for radiography and radiology in the medical field. And in the prior work we had hundreds of samples. You know, specific crack sizes, many of them at a certain crack size, a whole bunch in different crack size. Where we developed the POD base on the then data. And this is true UTs. It's true with x-ray. And the data follows this kind of a fit.

So when you run an experiment we have lots of samples and you bend the data we have lots of samples for each crack size categories. And you actually plot how many of those were detected and missed. So you actually plot the probability detection for the different teams, it has this kind of a --

CO-CHAIRMAN WALLIS: It's almost like a curve fit. When you get an A and a B you say that a ceratin team has a certain A and a certain B. So whatever the logic, you essentially eventually end up as a curve fit and it seems to work fairly well.

CO-CHAIRMAN FORD: Again, could you go back one? Stay there.

Those data points miss are based on 11 teams?

MR. SHACK: Yes. That's one team.

CO-CHAIRMAN FORD: Oh, that's one team.

MR. SHACK: If I put the 11 teams in there --

DR. KUPPERMAN: Because there's numbers in between.

MR. SHACK: You'd see some sort of solid band of green at the top.

CO-CHAIRMAN FORD: My question really was heading toward, though, what happens to those curves, your conclusion more physically realistic if you did a 100 teams? Is the number of data points you have there any -- does that come into this graph?

DR. KUPPERMAN: We have the law of confidence --

CO-CHAIRMAN FORD: Do you understand my question?

MR. SHACK: Yes. Yes. I mean, the number of teams, essentially gives me my confidence on my binomial probability. And if I had a 100 teams, I would have much more confidence that I had the true binomial probability of detection.

MEMBER KRESS: You could have put all those teams on there if you add another dimension at the top which was the height of some sort of bar on there to represent the number of teams, sort of a continuous fashion that hit those levels?

MR. SHACK: Yes. There are various ways.

MEMBER KRESS: You wouldn't have to just a bar, is all I'm saying.

MR. SHACK: Yes. I could present the data in various ways.

MEMBER KRESS: But this illustrates what you're doing, and that's kind of good.

MR. SHACK: Yes.

CO-CHAIRMAN WALLIS: Okay. And are you going to show you some data?

DR. KUPPERMAN: And now we're going to show you some data.

MR. SHACK: Some results.

DR. KUPPERMAN: The slide shows the --

now remember, these are the results for the resolution analysts. So this is the final result of the team. The primary and secondary resolution analysts --

CO-CHAIRMAN WALLIS: This is for one particular team?

DR. KUPPERMAN: Well, all the results you're going to see now are the average for 11 teams.

CO-CHAIRMAN WALLIS: This is the average for 11 teams then?

DR. MUSCARA: And it's the call they would have made for the field procedure. In other words, not the primary member of the team. It's the final call. It's the team's call, not the individual.

MEMBER KRESS: Now, when you say average, you mean you took all 11 teams and made a maximum likelihood and this is --

DR. KUPPERMAN: Yes. And one flaw may be --

MEMBER KRESS: It's not quite an average, it's a maximum likelihood?

MR. SHACK: It could be an example of where only five teams called it correctly and six missed and so it's the average.

MEMBER KRESS: Oh. You could do a maximum likelihood that way, you're right. It could be an average.

DR. KUPPERMAN: Okay. So this is a result for axial ODSCC at the tube support plate for example. And the blue line is the PLD and the red line is the lower 95 percent confidence limit that takes into account all of the uncertainty.

CO-CHAIRMAN WALLIS: So it's pretty well perfect?

MEMBER KRESS: No. Now your code up there is tube support plate, actual OD stress corrosion crack is that the way you read that?

DR. KUPPERMAN: Yes, that's correct. Longitudinally.

MEMBER KRESS: Longitudinally.

DR. KUPPERMAN: It's the longitude of ODCC, right.

MEMBER KRESS: Okay.

MEMBER SIEBER: So the point is that we're showing the results as a function of location. So this is tube support plate. There are other curves for tube sheets, there are other curves for freespan.

CO-CHAIRMAN WALLIS: You're saying this is the characteristic of the method of detection plus the method of observing? And this is a curve?

This doesn't say anything about what you need to do in terms of measuring depths or something, but you could at least put this into a PRA?

MEMBER KRESS: This is for PRA.

CO-CHAIRMAN WALLIS: It makes you an -- when you do PRA, say gee wiz, we'd better get a PRD that's ten times as big as this. This is a critical thing. That's good.

DR. KUPPERMAN: We want to point out that this is a test. You know, these analysts are coming in an they're really given a test. And there was the possibility that they would just call everything just so that they would not miss anything, ever. But they're following procedures and they're professionals. And we feel that they did a very competent job of assimilating how they would react in the field.

CO-CHAIRMAN WALLIS: It seems to me that this is related to the safety culture of the plant. I mean, there's a management person saying "Get this thing over with, I don't want to see any cracks today" or something. You're going to get a different result than if you have another kind of manager that says "Take your time. Make sure you do everything."

DR. KUPPERMAN: The culture is very important.

MEMBER BONACA: These teams, they're not necessarily only teams. I mean, there are teams of expert coming from vendors, right, to do --

MR. SHACK: Right. But they work for the plant.

MEMBER BONACA: They only work for the plant for the particular job. They go from plant to plant.

MEMBER KRESS: And best I re member, the POD was a very sensitive parameter in determining the actual list due to these events. As best I can remember in the PRAs that we've seen. So it's very important to get that.

THE COURT: But, I mean, we're not only relying on their professionalism, and we just have a low false call rate here.

DR. KUPPERMAN: Yes, that's what we want to point out that in most cases the false call rate is very acceptable and within limits that you want to get to.

The other point --

CO-CHAIRMAN WALLIS: I don't know you mean by false call. I mean, if there is a crack, which there are cracks at depth .4 and you only detect them at --

MR. SHACK: No, no. It's the cracks at depth zero we're worried about.

DR. KUPPERMAN: Only around ten percent of the test sections have a flaw. There's over 3200 test sections with nothing in it. But there's --

CO-CHAIRMAN WALLIS: Maybe I'm not understanding this curve. If you have a depth of .5, this says the probability of detection is only 30 percent? Is that acceptable?

MEMBER BONACA: About 50/50.

DR. KUPPERMAN: It's about 45, yes.

CO-CHAIRMAN WALLIS: It has to be all the way through before it's a very high probability of finding it.

MR. SHACK: It has to be deep.

CO-CHAIRMAN WALLIS: That doesn't sound very good to me at all.

MEMBER KRESS: Well, I mean, .5 is still a pretty sturdy piece of steam generator tube. So when you do the risk analysis for say not detecting it over the next inspection --

CO-CHAIRMAN WALLIS: Well, personally it doesn't look very good. I mean if the thing is --

DR. MUSCARA: When you look at the MRPC curve which relates to structural integrity, you get a better feel for that means.

CO-CHAIRMAN WALLIS: Okay. I think you got to do that.

DR. KUPPERMAN: Yes. That probably will make you feel a little bit better.

CO-CHAIRMAN WALLIS: Because I mean superficially as a member, just looking at this, I'd like to see a higher curve.

MEMBER KRESS: But this is the curve for the way we do it.

CO-CHAIRMAN WALLIS: So if this were breast cancer and you said there's a probability of detecting something which was half centimeter, only 50 percent, it would not be acceptable. For a scale of zero to one for nodal size, which would not be acceptable.

MEMBER KRESS: Yes, but if this the detecting of breast cancer that's not curable, then there it might be.

CO-CHAIRMAN WALLIS: Yes. But here you're saying the only thing that really matters if the really long cracks or the really --

MEMBER KRESS: Yes.

CO-CHAIRMAN FORD: Okay. Joe, if I could just again, a question of timing. If I take a break for a quarter of an hour, is this a good place after the next graph to take a --

DR. KUPPERMAN: I think we should spend a few more minutes to --

CO-CHAIRMAN WALLIS: Yes, when you give us the bottom line, I think it'll be time.

DR. KUPPERMAN: Because I think Joe's going to come back.

CO-CHAIRMAN FORD: Okay.

DR. KUPPERMAN: The only other point we have to make is that this is not the final POD. This triggers another analysis by the rotating coil and it's possible that the bottom coil could have correctly picked up a flaw and then the rotating coil could result in dismissing it. So it's the probability to PODs.

MEMBER KRESS: That would be like a false detection?

DR. KUPPERMAN: If there's no flaw, it's

a false call.

MEMBER KRESS: Yes.

MEMBER SIEBER: If there is but it's not confirmed, then it's a miss.

MEMBER KRESS: So this is not the curve you actually put in the PRA? It's the one you get when you factor in the --

DR. KUPPERMAN: The MRPC.

MEMBER KRESS: -- the MRPC? Right.

DR. KUPPERMAN: The other way of applying the PLD it's a function of voltage, and this slide shows the PLD as a function of voltage and with the 95 percent lower confidence limit. And we just point out that the PLD approach is .9 for the voltages, you know, one to two volts. And that is consistent with the observation in 1740.

MR. SHACK: We're sucking up.

DR. KUPPERMAN: And I tried to indicate a little bit an idea of why you might miss a law, and that is basically that there is a very high noise level, the signal was too complex and it results in analysis that doesn't lead to a call.

And very important, of course, are the human factors; fatigue, distractions.

CO-CHAIRMAN WALLIS: Or it might be

reluctance to pay attention to little flaws because you know they're unimportant.

CO-CHAIRMAN FORD: Again, could you go back?

The one to two volts is the limit current given in 9505, and yet as I understand it the POD that the staff uses is .6. Where do these conclusions that you're coming to right now impact on those two statements?

MR. SHACK: They'll be talking about that, I believe.

CO-CHAIRMAN FORD: Okay. So in other words, their current position they're taking at .6 is an over conservative approach?

DR. MUSCARA: It could be, but this is the reason for having the data as a function of different parameters. One question that often comes up is how does this information relate to what you see in the field where your noise level in the generators out in the field may be different, may be even higher. So we've been doing some work and try to adjust this kind of data to take into account the effect of noise.

Those are some of the things that need to be considered before we really decide that some of these curves can or cannot be used. But I'm sure that NRR may have some comments on that also.

DR. KUPPERMAN: We can almost skip this slide where we discuss these points that -- a call be made when there's no flaw. And even though the participants might --

CO-CHAIRMAN WALLIS: What is an overcall?

DR. KUPPERMAN: They're saying that there's a flaw, a false call, an overcall or false call.

CO-CHAIRMAN WALLIS: They're saying there's a flaw when there isn't one.

DR. KUPPERMAN: When there isn't one.

CO-CHAIRMAN WALLIS: That wasn't clear to m e.

DR. KUPPERMAN: And it's a very low rate except a little higher in the tube sheet.

CO-CHAIRMAN WALLIS: Okay.

DR. KUPPERMAN: Now, for missing flaws, this slide summarizes that. And mainly there's some distortion of a flaw signal that would be very clear. And this could be caused by geometry of deposits or the crack could be very tight and doesn't generate a signal above the threshold that they're looking at.

And the last bullet indicates that sometimes when you're going through this complete analysis, one coil might say there's a flaw and another one might say there isn't. And that leads to confusion and discussion by the resolution analysts. And it's related, often, to the possibility that there's a very high phase angel which is generally attributed to no flaw even though there is one.

CO-CHAIRMAN WALLIS: It's number three there. If you have a flaw that ran the whole length of the tube, it would become the norm and you might not see it at all.

DR. KUPPERMAN: Yes. If it's a very long flaw, the circumferential coil while it's going through the middle of it, would not give you a large signal. It's the beginning and the ends that you pick them up.

And the other point that we discussed is that there could be a perceived idea of what a flaw response should be like and then might not pursue anomalous indications. And then the human error. Sometimes it's a recording error, actually. And often lack of concentration.

This gives you a little bit of an idea of how a problem could arise, and probably the most difficult situation for an analyst to deal with regarding the bobbin coil signal. This is when you have a stress crack in the dent. And the first list that you would figure A shows the tube support plate signal without a dent or a crack.

CO-CHAIRMAN WALLIS: Where's the dent in the tube as it goes through the --

DR. KUPPERMAN: The dent is in the tube at the tube support.

CO-CHAIRMAN WALLIS: As it goes through this whole thing?

DR. KUPPERMAN: And then B shows a tube support plate. B and C showed with a dent, and the crack -- the figure gets complicated. And then D and E show a shallow and a deep crack. And they're supposed to figure this all out.

And what they do in this kind of situation is they're very conservative and they basically, if they can't resolve this cleanly, they'll just call it with a bobbin coil and rely on the rotating coil to resolve the issue. So what that leads to is a very high false call rate, which gives you this kind of POD curve. But what really happens is that after the call, even though there's an overcall, you have to look at it with the rotating coil generally speaking. And the rotating coil is very good at separating out the crack from the dent, and so the final result is more reasonable although it's still miss them in this kind of situation.

MEMBER SIEBER: It seemed to me it was a matter of practice to just automatically use the RPC in certain tube support plate locations for pretty flawed steam generator rather than go with the bobbin and make calls and reexamine the ones that get called.

DR. KUPPERMAN: It's possible to do a 100 percent examination of the support plates with the rotating coil, but it would certainly take a long, long time.

MEMBER SIEBER: It's time consuming.

DR. MUSCARA: Well, in effect, it's typical to do a 100 percent at the tube sheet area where the inspect was, but they only inspect something like three or four inches.

MEMBER SIEBER: Well, maybe five or six because you're down in the gap of three and you got to get above and below. It depends on much crude is sitting there, too.

CO-CHAIRMAN WALLIS: I have a question for Bill. And it looks as if all this work was done by a subcontractor called Pioneering Science and Technology. Who is that?

MR. SHACK: That is a directive from the laboratory director that we will put that on all viewgraphs.

CO-CHAIRMAN WALLIS: But it doesn't say anything about you guys.

DR. KUPPERMAN: That's Argonne's slogan.

CO-CHAIRMAN WALLIS: Okay.

MR. SHACK: We didn't choose it.

DR. KUPPERMAN: I wanted to use this slide again to point out that even in a clean, relatively clean straight tube three span no tube support plate, no dent you still can miss a flaw because the signal just doesn't jump out as it's flying past. But in this particular case we analyzed this tube section and found a nice correlation between the multi-parameter algorithm result and the destructive analysis --

CO-CHAIRMAN WALLIS: Everybody should use it. Yes.

DR. KUPPERMAN: But that's the kind of thing that can happen, just an example.

MR. SHACK: Not all the teams missed it, but some did.

DR. KUPPERMAN: No, no. Just some. Not everybody missed this.

CO-CHAIRMAN WALLIS: How would it be if we read a report saying forget about all these teams, just use the Argonne method? It seems to be so much better for many purposes.

MR. SHACK: You know, there's a economic penalty to the analyses.

CO-CHAIRMAN WALLIS: Oh, maybe not. These teams must be expensive.

MEMBER BONACA: Also these people are pioneering.

CO-CHAIRMAN WALLIS: Well, I know. This is a fast moving area.

DR. MUSCARA: I think people are looking at it.

MR. SHACK: A couple of more slides before we take a break.

Just indicate that with all these qualifications, procedures and so on we find generally that the results are consistent. And this shows the team variation. This is the 11 teams and straddling the PLD curves for the 11 teams. But this doesn't always happen.

And so this one is difficult to explain because there's a team that's way out of line here.

CO-CHAIRMAN WALLIS: That extreme one is also a team, that green team.

MR. SHACK: Yes, the green line is a team. And you might find that one team is better in the tube support plate and one is tube sheet --

CO-CHAIRMAN WALLIS: So that the utility with the good safety culture would pick a green team to hire. The one with a bad safety culture would pick the --

DR. KUPPERMAN: No, but as Dave said, they up and down depending on the --

CO-CHAIRMAN WALLIS: Oh, it's not consistent.

MR. SHACK: Some are good, you know better at tube sheets, some are --

CO-CHAIRMAN WALLIS: It's random which one happens win the game with which crack or which location?

DR. KUPPERMAN: The bottom line is there wasn't really one lousy team.

CO-CHAIRMAN WALLIS: Okay.

MR. SHACK: And then you can also

present the results for the -- and you see the POD curve and the 95 percent low confidence limit. It's a little higher false call rate for that one.

CO-CHAIRMAN WALLIS: So all these curves, we need to establish them or go into some sort of a PRA that says that you're likely to detect a crack of a certain kind of a tube sheet and detect a crack somewhere else, so on and so on?

MR. SHACK: It tells you something about the population of cracks that you might have. You know, although you do inspections, you miss cracks. And so it tells you what kind of cracks that you might be missing.

CO-CHAIRMAN WALLIS: So the whole question of how you should do inspections and how many tubes you should inspect and how frequently is a different question altogether, isn't it? But this would be useful information for making that --

MR. SHACK: It's part of that question, right.

DR. KUPPERMAN: As already pointed out, the depth does not fully characterize the structural impact. And what you might want to look at is the PDL is a function of m_p. And that's what we've done. And this is an example of the tube support plate LODSCC. And what you're looking for is what's the PLD for m_ps greater than 2.3, which is the -- and it's very high.

CO-CHAIRMAN WALLIS: This is very good. But to get back to my previous remark, the decisions made about inspection frequency seem to be someone's almost picked out of the air and made a very simplified way rather than using -- maybe they could use this kind of information and a knowledge about how cracks develop with time.

DR. MUSCARA: They could use and they do use it sometimes, this kind of information.

CO-CHAIRMAN WALLIS: They do?

DR. MUSCARA: When they do an operational assessment.

CO-CHAIRMAN WALLIS: It's such a level of detail compared with some of the way decisions get made in inspection.

MEMBER BONACA: Now, if you did inspect steam generator tubes at every refueling, okay, when it shutdown, wouldn't the probability improve in that you have a history of previous signal that gives you some intelligence on what may still propagate, etcetera?

DR. KUPPERMAN: History is very

important. When you say an indication, you look back and see was there an indication on the previous outage.

MEMBER BONACA: That's right.

THE COURT: We don't have that history. There is a difference.

MEMBER BONACA: No, I understand that. But I'm saying the real world, because I know in some cases the inspections are being faulted for not having identified previously the effects that should have been identified, hopefully, and that may be some of those cracks which are lingering in it. But in reality, I mean it should be the reverse will be true that in general when you stay with the steam generator I guess you are learning about which defects may be there, which may propagate and then if you don't see them again next time, that confirms that's probably not a defect and so on and so forth. So you would have quite an effect, I would imagine, on this probability distribution.

MEMBER SIEBER: Well, you actually have to make that comparison because that's where you get the crack growth rate from.

MEMBER BONACA: Yes. You see these tests are done --

MEMBER SIEBER: It's an important parameter to say prospectively I can safely operate for the next cycle. If you don't have that history, you can't make that prediction.

MEMBER BONACA: Because here you have no previous intelligence, but there you do. I guess I'm curious to know how much it would effect your -- you know, because people, you are going to call in the same team that did the previous evaluation and they remember which one that were put aside, which one were questioned.

DR. MUSCARA: Part of the process in industry before the inspection is to conduct a degradation assessment. When they conduct this degradation assessment with the inspectors, they're going to inspect the plant. They essentially take into account prior histories, so the inspectors know what that history is.

When we conduct our tests, of course, our mock-up was, let's say new, this was the first time that someone looked at the cracks. But we also had a degradation assessment. And that degradation assessment with the teams. And they had information on the kinds and types of flaws that might be there, the conditions that might be there. So they had some information, and it's not as if this was all cold. They had information about the history of our mock-up.

CO-CHAIRMAN WALLIS: Well, I think the bottom line is you've got a method here for establishing these POD curves. And I think we'll accept that. I wonder if we need to see anymore? But I'm very interested in the X-probe, because it seems to be getting more data, therefore more information. And by processing it analytically, you can get far better understanding of what's going on than just getting for an expert to look at even more terabytes of data. That seems to be the way to go.

DR. KUPPERMAN: Well, I agree with you that the array probe is the way to the future, is the probe of the future.

CO-CHAIRMAN WALLIS: Well, I mean, imagining is an area of engineering which has developed at an extraordinary rate. You can buy better imagining things in all kinds of fields because of the way computers and understanding goes. It's developing very, very quickly. So it seems like an X-probe out to be available for use.

DR. KUPPERMAN: Well, it's used quite extensively in Canada.

CO-CHAIRMAN WALLIS: Yes. So why do we have this antique way of looking at things which is subject to misinterpretation?

DR. KUPPERMAN: The X-probe is being used in the United States more and more, but right now, I don't know. I don't know how many plants have actually used it, but some -- certainly in a replacement steam generator, I'm pretty sure they did a 100 percent inspection with the X-probe.

I think this is a time for break.

CO-CHAIRMAN FORD: Okay. Could I suggest that we adjourn for a quarter of an hour. So, say, 11:00 back here.

And thank you much.

(Whereupon, at 11:43 a.m. a recess until 11:03 p.m.)

CO-CHAIRMAN FORD: WE're back in session.

We've got an hour and a quarter to finish off this whole question of 3.6, 3.7 and 3.8. Is there a lot more to be done on 3.6?

DR. MUSCARA: About half of an hour, I think.

CO-CHAIRMAN FORD: Half an hour?

DR. MUSCARA: I think on the other items

it's just -- it's barely 15 minutes or half an hour on the other items.

CO-CHAIRMAN FORD: Okay. Jolly good.

DR. KUPPERMAN: So we'll continue now to address the eddy current noise issue. The question is how much eddy current noise can you tolerate before the data quality is affected and detection capability degraded. As a result of low signal noise there are several things that could take place.

If the noise is the result of some kind of an electronic problem or maybe the probe is worn out too much and resulting in high noise levels, you could just recollect the data. Do it again. Or you could even possibly result in the change of technique. Or you could determine what the detection probability is in this noise, in the presence of this noise and adjust the POD and sizing uncertainty accordingly. Or all these options may not be exercised, you might just repair the tube if its an isolated case.

CO-CHAIRMAN WALLIS: I think a question might be whether there's more noise in the plant than there is in Argonne.

DR. KUPPERMAN: Most plants have a

higher noise level than in the mock-up, but not all. The question then is how can we adjust the PLD curves for situations with better noise. That's one of the issues which we address.

MEMBER KRESS: What causes the noise in an eddy curve probe? Is it flaws in the tubes or in actual --

DR. KUPPERMAN: Could be --

MEMBER KRESS: -- isn't that what you're looking for and how you run the probe in and out.

DR. KUPPERMAN: Well, part of it could be the probe. And then if you realize if it's the probe, you can just change the probe.

MEMBER KRESS: Change the probes, yes.

DR. KUPPERMAN: But it's deposits, permanently variations, it could be something in the microstructure, maybe it can be localized, geometry --

MEMBER KRESS: But it's not something that's externally applied? It's just because of the tube characteristics and the way the --

DR. KUPPERMAN: Well, the deposits on the tube --

MEMBER KRESS: The deposits on the tube. But I'm not calling that's external.

DR. KUPPERMAN: Cold walling and rippling from the working.

MEMBER KRESS: So these are natural things that are there?

DR. KUPPERMAN: One issue is how do you measure the noise and this is an issue that's discussed extensively throughout the industry.

We had a meeting at Argonne with experts from the industry to discuss the noise issue and how to deal with it. One of the simplest things you could do is to measure the RMS noise, but it really isn't a good measure for detection because in the way that the signal is generated by a flaw, you really want to look at the so called vertical component.

I mean, you -- at Y axis and Y axis and you're basically looking at a jump in the signal in the Y axis. So you don't necessarily want to measure the entire signal because it could account for the noise that you could easily -- a signal that you could even dismiss.

Now, the other problem is that a noise level that might significantly affect detection -- that may not significantly affect detection could have a profound effect on the attempts to sizing.

CO-CHAIRMAN WALLIS: I'm going to ask you again about this noise. I mean, this is the noise -- if you just leave the probe in one place, you're not traversing at all, do you get wiggles in the signal because maybe the probe is isolating in the tube or something?

DR. KUPPERMAN: Wobbling the probe is a probe?

CO-CHAIRMAN WALLIS: It isn't centrally in the tube? And isn't there's always some clearance and so on --

DR. KUPPERMAN: Resolve the clearance changes, things like that.

CO-CHAIRMAN WALLIS: I noticed that the rotating one that you handed around wasn't straight, so that might make a difference. Someone dropped it.

DR. KUPPERMAN: Well, I didn't bring one that we use.

CO-CHAIRMAN WALLIS: So there are things like that that it's -- I mean, the real physical causes for this?

DR. KUPPERMAN: There are physical causes --

CO-CHAIRMAN WALLIS: You know, even if

it started in the tube just sitting there, it could pick up something which is oscillatory?

MR. EMERSON: The probe itself could be a problem. That's, of course, the simplest thing to fix. That's true.

MR. SHACK: U bends are associated with probe wobble, for example.

CO-CHAIRMAN WALLIS: Well, I guess a dent, I mean if it goes by a dent it moves over to one side and -- because it's got to be smaller than the tube to get in there by a certain amount to account for the variations in the tube.

DR. MUSCARA: The elements are also spring loaded, so you get a larger fill factor as you can get. So, yes, there is some probe wobble, movement, but that's also limited. I think a lot of the noise we're talking about is noise that's there inherently in the generator because of things like copper deposits and magnetite treat treatments.

CO-CHAIRMAN WALLIS: So there are real things there which are not cracks that effect --

DR. MUSCARA: Right, that produce --

CO-CHAIRMAN WALLIS: Not what I would think of as extraneous noise due to picking up radio signals from something or something like -- an external signals which have nothing to do with it.

MEMBER KRESS: Yes, that's what I was asking.

CO-CHAIRMAN WALLIS: Yes.

DR. KUPPERMAN: One of the key problems is that that's how you measure noise and you measure it at some location away from where the flaw is actually located. That may not give you the information you need. You really need to know what the noise level is at the location of the flaw. And that's one of the difficult issues to deal with.

At Argonne with the mock-up we have noticed that we need a signal-to-noise ratio greater than 2 to 1 to assure that you've have a 90 percent probability of detection for those mock-up flaws. And this ratio of two to one is consistent with the results that have been presented by our Canadian colleagues. They also come to that, pretty much the same conclusion, that that's the kind of a signal-to-noise ratio that you need to get very high probability of detection.

CO-CHAIRMAN FORD: But presuming that ratio is a good deal higher for the current commercial techniques, not just your m_p techniques, the analysis of it?

THE COURT: We're talking about using the current commercial techniques.

CO-CHAIRMAN FORD: Okay. It's just that you said that Argonne --

DR. KUPPERMAN: You can detect flaws less than -- you can detect flaws when the signal-to-noise ratio is 1.1 if you're familiar enough with the pattern that might be generated.

CO-CHAIRMAN FORD: Okay.

CO-CHAIRMAN WALLIS: But this must depend on the size of the floor. I mean, you have a piece of size magnetite there which shouldn't be there, that it means that it behaves as if it were a flaw, which is .2 thickness or something. So I have real trouble detecting small flaws. But a big flaw would be fine.

DR. MUSCARA: Well, again, it depends on the earlier discussions. If the big flaws don't have a big response, and very often they don't.

CO-CHAIRMAN WALLIS: Well, then that's the problem, too.

DR. MUSCARA: Then it's buried in the noise.

CO-CHAIRMAN WALLIS: That's the problem, too, yes.

DR. KUPPERMAN: The work at Argonne regarding the mock-up involves simulating the noise that we observe in the field. and we can do these electronically. We can add noise to a flaw signal and then determine if the flow could be detected, and we could vary the noise.

So here's a flaw, here's noise and we can combine it to create this --

CO-CHAIRMAN WALLIS: Jungle.

DR. KUPPERMAN: -- signal which is not to easy to --

CO-CHAIRMAN WALLIS: I think the right hand thing would baffle.

DR. KUPPERMAN: And we're doing this to a variety of flaws in the mock-up. And then we will have readjusted POD curves for the various noise levels that we --

CO-CHAIRMAN WALLIS: Well, is this an aggregation here? I mean, that noise looks as if it's overwhelming the signal.

DR. KUPPERMAN: Well, this is an example of it.

CO-CHAIRMAN WALLIS: It's an extreme case?

DR. MUSCARA: No, I don't think so. I

mean --

CO-CHAIRMAN WALLIS: No? This is really what you can have?

MEMBER SIEBER: Well, no, you can have noise levels that high, but that would be on the upper end of noise. Because the applitude is comparable to amplitude of the flaw.

CO-CHAIRMAN WALLIS: That's terrible.

DR. KUPPERMAN: So it can, as you can see, create a lot of problems.

CO-CHAIRMAN WALLIS: Wow.

DR. KUPPERMAN: Bill will now finish up this part.

MEMBER BONACA: Yes, I don't know much about this field here, but the question I have is averting SCs at the current, is there any other technique that one could imagine that could supplement or compliment what you're doing here?

DR. KUPPERMAN: Efforts to evaluate ultrasound probes.

MEMBER BONACA: Okay.

DR. KUPPERMAN: The Belgiums use ultrasonic probes in some cases. There have been -- there's been some work in the United States to look at all kinds of ultrasonic techniques.

On the treating possibility is to use a ramwave, the platewave that would send a signal to the entire tube and you would be looking at echoes in the scattered pattern that would give information in a second about the entire tube, but the results have not been satisfactory.

MEMBER BONACA: What about in supplementing with something eddy current? I mean, I understand that there is a concern about the time you spend doing this, but --

DR. KUPPERMAN: Ultrasonics are also rather slow because -- well, after the ramwave, but that didn't work. But if you have a rotating probe going around, it's very slow. But the advantage would be, especially in crack depth measurements, if you could get enough of a signal off the cracked tip, then you could use a crack tip echo to estimate the depth. And a lot of work is being done by EPRI to try to validate a technique that they're developing for that specific purpose. But, you know, it's still in the -- it's not ready to be used right now.

CO-CHAIRMAN WALLIS: If you go back to your previous slide, I can't believe this is realistic. I mean if the real signal should be on the left, and that's how I see a flaw --

DR. KUPPERMAN: Right.

CO-CHAIRMAN WALLIS: The one on the right, the guy looking at that can either say it's almost all noise except for the big one, which is a crack. All he could say I've got a thousand cracks in here, whatever. I mean, they could all be cracks, all those giggles could be cracks. How does he know which is a crack and which is noise? Does he sort of say I can't believe there are that many cracks, therefore it must be noise except for the big one?

DR. KUPPERMAN: Well, what you would say is that the noise level is so high that the probability now of detecting a flaw with a depth of 80 percent drops from, let's say, 90 percent to maybe 50 percent. So basically the idea is that you could still see a flaw in very large --

CO-CHAIRMAN WALLIS: Because it would be a deviation of this pattern of noise?

DR. KUPPERMAN: It would stick up, way out.

CO-CHAIRMAN WALLIS: It would be a deviation from the background pattern.

DR. KUPPERMAN: Which the ones that have

a smaller amplitude are comparable to the noise would not be there at all.

CO-CHAIRMAN WALLIS: It would disappear, it would disappear, right.

DR. KUPPERMAN: And so you would have an adjustment in the POD or you would plot the two.

DR. MUSCARA: If there's a question about the signal and the inspector decides to call it, then the next steps are to use at that section of signal, use the different frequencies --

CO-CHAIRMAN WALLIS: What sort of frequencies do they use?

DR. MUSCARA: And they also take a look at the data --

DR. KUPPERMAN: 100 to 400 kilohertz for the bottom coil. Typically 300 kilohertz --

CO-CHAIRMAN WALLIS: Three hundred kilohertz.

MR. SHACK: One of the things we're concerned about is to estimate the impact of noise. As we've said, we've talked about characterization of the noise. We've also noted that the noise level in the mock-up is less than in most plants. So we somehow have to be able to estimate the impact of this higher noise on the PODs that we determine in the round robin. And we've looked at two approaches to do that.

I discussed the Berens model for probability of detection before where, again, we had a response that was normally distributed and the POD was basically based on the idea that the response would achieve the noise level. And so it turns out that in that case the shift in the curve of very simple, it's basically the delta noise over that thing that characterizes the spread in the response.

Now, again, the limitation of it is of course is we pretend that the response is in fact the vertical component of the bobbin coil, and really the response is a pattern recognition scheme. So we're making a kind of an assumption here that it's a good enough surrogate for the response that we can use it. And, again, that's something -- we wanted to look at a different way of approaching this that didn't have to make that assumption.

And then the other one was to go back to an empirical determination of the probability of detection at the function of the signal-to-noise level. And we could do that with the data in the mock-up, but we had a probability of detection for each of the curves. As I'd mentioned before, we had measured the depths of each of the curves. We could also measure the signal-to-noise level of each of those curves and instead of characterizing the probability of detection of detection in terms of the depth, we would characterize the probability of detection in terms of the signal-to-noise.

If you take that piece of data, POD is a function of signal-to-noise, then we have a different correlation which is signal-to-noise is a function of depth and we can essentially convolve the two to get back to a POD as a function of death, which is our classical POD curve. We can account for the noise by essentially changing the signal-to-noise as a function of depth. That is, we would simple say that for higher noise levels we would decrease the signal-to-noise for those depths and adjust the noise that away.

And, again, the limitation of the bobbin coal response is sort of accounted for in this empirical POD versus S/N curve; that we don't simply have a simple threshold level which is kind of the Berens model which says, you know, when your response gets to some level, bingo, you suddenly can detect it. We actually have a kind of a POD curve that takes into account the fact that not all signal-to-noise levels are equal, and in fact --

CO-CHAIRMAN WALLIS: I don't think all noise levels are equal either. There may be noises that look like cracks and the noise that looks like a --

MR. SHACK: Yes. Now again, we've already assumed that we're characterizing the noise in the best way we can, which is the vertical component of the voltage local to the flaw.

CO-CHAIRMAN WALLIS: But if the noise were a random sort of thing, then that's very different from a noise which is a magnetite deposit which looks like a crack which may be here, there and there and therefore it produces a blip without any background noise anywhere else. That would probably be called a crack, although it's really noise.

DR. MUSCARA: Those noise doesn't look like a crack once you start looking at the base.

CO-CHAIRMAN WALLIS: So it doesn't look like a crack. But if you have things that look like cracks which were noise, then you would be in trouble.

DR. MUSCARA: The only thing we run across that looks like there's a cross is when there's a tubing that's cover with copper and if for some reason there's a little chink of copper missing, that produces a crack-like signal. But the other noise sources --

CO-CHAIRMAN WALLIS: The other noise doesn't look like a crack qualitatively. That's a different -- okay. So the quality of the noise makes a difference here?

MR. SHACK: Well, Joe's argument is an argument for the Berens model where the only thing that counts is the kind of level of response.

CO-CHAIRMAN WALLIS: Now this 300 kilohertz is the range of frequencies of some AM radio stations, isn't it? You've got a big antenna sitting up there in Argonne --

DR. KUPPERMAN: It's not in the range of area stations.

CO-CHAIRMAN WALLIS: It's not? It is. Long waves.

DR. KUPPERMAN: AM.

CO-CHAIRMAN WALLIS: Yes, long wave AM is -- anyway.

DR. MUSCARA: WE're talking kilohertz.

CO-CHAIRMAN WALLIS: Yes. Long wave AM. Long wave AM. The kind of long wave that comes from the ship-to-shore.

CO-CHAIRMAN FORD: So from a procedural point of view, Bill, if you walk into a plant, plant A, and you're looking at their steam generator tubing do you just do an eddy current analysis on a part of the tube that you're pretty sure is not cracked as you use that as the patent recognition formulation that you use or then you're subtracting that out from anything else? Because that can vary with cold work, magnetite, copper all these other background --

DR. MUSCARA: That's how --

CO-CHAIRMAN FORD: Is that procedurally how you do it?

DR. MUSCARA: They go into a green portion of the tube to measure the noise. And our recommendation we go into the area where we expect the crack and measure the noise around that area.

DR. KUPPERMAN: -- and then they see if the noise level is lower than the EPRI guidelines so that they can proceed.

THE COURT: And that's a very good way to treat certain kinds of noise, you know. The probe ware noise, that's a reasonable sort of thing. It may not be the best way to determine a noise level to use in this adjustment of the POD curve, in which we suggest that you use a noise measurement essentially in the area where you're looking for the crack. It's more difficult to characterize as a signal.

And, again, when we look at this -- you know, our noise level is not -- that is, we think the noise level in the field is somewhere between what we have in the mock-up and about twice the noise level we have in the mock-up. That if somebody actually had higher noise, they'd be out there working in the inspection to find some way to get the noise level down. They probably wouldn't try to actually do an inspection with noise levels much higher than that. So there is a certain range of levels of interest here that we think that people actually do work in.

And what I wanted to show here is that I've shown my essentially originally determined POD curve and then my reconstructed curve used the POD as a function of signal-to-noise, and then the signal-to-noise with depth to reconvolve back a POD as a function of depth. So, again, my mechanism at least gives me back my original curve. I then apply my higher noise level and then convolve that back with my POD as a function of signal-to-noise and I get a new lower curve at the higher noise level.

And I can compare the two approaches. The Berens approach where I simply shift the mean curve by the noise over the spread and responses and the more complicated case. And at least the comforting thing is that I seem to get answers that aren't too different. So I've taken two fairly different approaches to doing it and come up with answers that are not too different. And our feeling is that these curves kind of bound the range of responses that one would expect. If you don't expect to find noise levels much higher than those represented by the lower curve --

CO-CHAIRMAN WALLIS: So when you say signal-to-noise ratio, your metric is amplitude or maximum amplitude or what is it?

MR. SHACK: It's the vertical voltage. The vertical component of voltage.

CO-CHAIRMAN WALLIS: It certainly isn't an RMS, because the signal has a very low RMS. It's only there some of the time. It's a peak.

MR. SHACK: Yes.

CO-CHAIRMAN WALLIS: It's a peak. The signal is an occasional blip.

DR. KUPPERMAN: We have been --

CO-CHAIRMAN WALLIS: Well, they already established the signal is nothing because most of the tube there's no signal at all.

MR. SHACK: There's a window that you select over which to do the averaging.

CO-CHAIRMAN WALLIS: Ah.

DR. KUPPERMAN: And with that, we recommend a side window rather than a fixed window.

MR. SHACK: Starting to get down to the details we hope to skip over here.

CO-CHAIRMAN WALLIS: Well, you're in pretty deep detail already.

DR. KUPPERMAN: Okay. The last topic is the --

CO-CHAIRMAN WALLIS: This is the one everybody should be using.

DR. KUPPERMAN: The advances in the array probe, and specifically we'll talk about the X-probe.

It has 36 coils essentially going around its circumference and it's based -- rather than a pulse echo type probe.

It has great advantages, one of which it can move through the tube as fast a bobbin coil while at the same time gathering information almost as detailed as a rotating pancake one. The difference is that since there's only a limited number of coils going around the tube, you don't get as many points in a circumferential scan as you would with a surface riding pancake coil that's picking up 83 times -- so there is a slight difference in the spacial revolution.

The use of this, I believe and I think -- will increase in time as automated procedures for the data analysis are developed and they are currently being developed by industry. To do a full generator with an X-probe would require terabytes of data. And that tends to slow the analysis down, but as I said, as these procedures that are being developed come validated, I think that you'll see it no more. And there are plants in the United States that are being scanned -- inspected with the X-probe.

CO-CHAIRMAN WALLIS: These ones that are being used -- you've got part of the scheme, but not the rest?

DR. KUPPERMAN: Right now they're done without automated procedures.

CO-CHAIRMAN WALLIS: Yes.

DR. KUPPERMAN: But there's development. Argonne's actually involved a little bit with -- actually a lot but not necessary me, with the development of these automated techniques --

CO-CHAIRMAN FORD: Now where is this X-probe, who has developed it?

DR. KUPPERMAN: The X-probe is AECR and RD Tech combined effort.

MR. SHACK: But we should mention there are other array probes.

DR. KUPPERMAN: There's another one from -- there's the MHI intelligent probe that is comparable. And that's being loaded by a company --

DR. MUSCARA: I'd make a comment maybe. It's not in our mission to develop -- to look for which probe is the best. What we're doing is clearly for those techniques that are currently used in the field, we needed to quantify their reliability. So when industry comes in with a claim that they've detected or not detected a flaw, we would like to know what was the probability.

Now, the reason the X-probe was in the program, because in the program we also have a task to evaluate evolving techniques that have a good chance of being fieldable and used in the field.

And so we want to get ahead of the game to quantify its capability also.

And since the Canadians are participants in our steam generator international program, we've made use of their technology and their teams to evaluate this probe also. But we're not out there to look for what's the best probe. We want to know what is the capability of the probes that are being used or have a good potential of being used in the field.

DR. KUPPERMAN: This slide gives you a comparison of the imagining techniques. The imagining results. So the lower left would be the standard X with the standard plus point amplitude 3-D image of the flaw. And you would have to go in and analyze either the -- figures and it's somewhat complicated for this kind of flaw. But when we took a look at the same flaw with the X-probe the result is divided up into two images, one of which is looking only at axial indications and the other one is looking at circumferential indications. So you immediately see in this case that this a circumferential crack and it's obvious.

CO-CHAIRMAN WALLIS: I'm trying to think about what the ACRS intended, and it's all in memory. But I'm just trying to think what Dana was saying.

The impression I got from some of the things Dana said was that we were not just saying you need to know better how good your measurements are today, I think we were also saying you really need better measurements. I think that was part of the ACRS intent. And this is in response to that, that idea. I don't think we were just saying you want to know better, though you certainly did, the faults of some not very good way of measuring but really there ought to be more reliable better ways of measuring. I think that's what we were saying. But, again, this is just from memory.

DR. MUSCARA: I think the key comment really in the ACRS recommendation was that the points -- that the fixed value of POD was not realistic. And at that time we already had a great deal of work going on. And you said well look, we're looking at POD, not just at the point value for a single parameter, for the different flaw parameters and their value entirely over the entire size range.

And I guess I must say we're doing other work that's related to eddy current which we're not covering, but the idea here was let's address the specific comment of the fixed value and other related interesting information. But I don't think we're responding to the need to do better inspection.

CO-CHAIRMAN WALLIS: This is a very strange kind of industry this, because there's all this emphasis and knowing better how good or bad what we've got is whereas the engineering solution to most things is to have a better design and a better way of detecting than -- that's the natural thing you do in most industries rather than falling over to get better understanding of how bad your present method is.

DR. MUSCARA: Well, how better, how good; this information goes into probabilistic fraction --

CO-CHAIRMAN WALLIS: I know. I know.

DR. KUPPERMAN: Well, finishing up on this slide, I just wanted to emphasize again that the X-probe and the plus point probe provide an amplitude profile, whereas the multi-parameter algorithm gives you the depth profile that allows you to do cross sections.

I can go fairly right to this last curve that summarizes the difference between the results for the mock-up using the X-probe versus the composite team result. And you can see that it's at least as good, if not a little better -- it is a little better, actually, for the deeper flaws. And that was a pretty -- you know, that was a result that we got.

Down at the bottom --

CO-CHAIRMAN WALLIS: It's surprising it's not much better, is it?

THE COURT: Well, I mean axial cracks are something bobbin coils are pretty good at, you know. The thing about this is if we looked at the tube sheet and then the cracks, you get a higher speed --

CO-CHAIRMAN WALLIS: This is indicating to me that almost any one of the select eddy current or -- sophisticated you make it in terms of looking at small depth cracks.

MR. SHACK: That's probably true.

CO-CHAIRMAN WALLIS: Must be.

DR. KUPPERMAN: Okay. Let me point out that this curve is a result of going through the entire mock-up with a bobbin coil and then going back with the rotating coil and doing an analysis and so on. And this is one fast scan without analyzing the data. This does take, obviously, longer to analyze the data but it's empirical in the integrated effort right now to the integrated effort with the bobbin coil -- you can review the summary slides.

Okay.

DR. MUSCARA: All right. Then I think we move on to 3.7 and 3.8.

CO-CHAIRMAN FORD: There are so many slides that are just repeating what's already been said.

DR. KUPPERMAN: Yes.

CO-CHAIRMAN WALLIS: Well, it addresses the issue that improvements can be made and you've made improvements. Now, how well did you do?

DR. MUSCARA: Well, I guess we were addressing again the item which was 3.6 which related to POD. And I think we've characterized the techniques that we use quite well. And provided you with information that was beyond that fixed value of POD and goes beyond just the voltage. We have the MRPC and the actual crack size correlations. So I think that's what was in the action plan. That certainly has been achieved. And I think we have gone beyond and have provided you with additional information.

CO-CHAIRMAN WALLIS: Well, do the improvements have any impact on reactor safety?

DR. MUSCARA: Well, you know, there are a number of different ways to get there. When we look at performance based regulations, we don't specify the technique that they should be using. But if it is a technique that it is not reliable, they may have to do more frequent inspections. If they use a technique that's more reliable, they don't have to be quite as frequent.

Some of the improvements come about not necessarily because we're using a better technique, but if in your personal assessment if you need to --

CO-CHAIRMAN WALLIS: So I guess we could conclude that if it turns out that all the decisions are the same as they would have been without the improvements -- it's sort of interesting, but the ACRS was asking you to do something which really didn't have any effect.

CO-CHAIRMAN FORD: The issue I think has been addressed in 3.6 in NUREG-1740, was this whole question of POD, do you have a process or a methodology to predict the changes of POD as a function of voltage that -- things of nature, rather than relying on the POD at .6, which is what you're currently using. And the answer you've got a methodology. How good it is in answering the overall question about PRAs, that's still to come as you develop your program.

As to the question of the POD at .6 as to whether that is always conservative or not, I think what you're showing is and you mentioned that Louise was going to address that particular topic, is that correct, and right now? Is that right?

DR. MUSCARA: Yes.

CO-CHAIRMAN FORD: Okay. And the other question that came up in 1740 was this observation that some of these methodology developments for POD must be a function of improvements in techniques. And you've addressed that to a certain extent with the X-probe. In fact, it doesn't change that much from the graph that we showed you. But okay then, that's the fact. It doesn't change that much. The resolution might change, but not the POD.

DR. MUSCARA: I think we need to be careful also about whether it changes the capability. Because if you look just at the bobbin coil -- this is used for screening inspection.

CO-CHAIRMAN FORD: Right.

DR. MUSCARA: So the bobbin coil by itself may miss flaws in different locations. This other probe, the X-probe has better capability on a single step to detect the flaws. What you're looking here is the combination of the result when you've look at with the bobbin coil plus the rotating probe for a specific location at the support plate, because that's the procedures that's in place these days. But if you're looking for a flaw anywhere in the generator and you have not pre-knowledge of it, the X-probe should be doing a lot better with respect to detection on its first step without any other follow up than the simple bobbin coal.

And I'm not sure also that I -- you know, when you say we developed for POD, we in fact have quantified the probability of detection for the current used techniques for the different kinds of degradation.

CO-CHAIRMAN FORD: Yes.

DR. MUSCARA: And we've done it as a function of --

CO-CHAIRMAN FORD: But if you've done an individual -- at DPO, there's a whole question of whether you should -- for POD prediction, there's a question of whether you should be using a log-log process or this one that you're using. I think what you're showing is that the one that you're using is defensible because it wasn't clear that it was before.

CO-CHAIRMAN WALLIS: Are we going to move on or are we going to stop here?

CO-CHAIRMAN FORD: No, no. We're going to quarter past 12:00.

I have one last question. All of these developments we've been talking about, I would assume they'd apply equally to 690 as it does to 600? I can't think of a physical reason why it should not, but is that true?

DR. MUSCARA: We have in this work not looked at 690, but my feeling and I think in general that there are not that many differences. 690 tends to be a little bit less noisy, so any difference it's going in the right direction. 690 will not be worse than the 600.

CO-CHAIRMAN FORD: Okay.

DR. MUSCARA: We haven't at this point physically tested 690.

CO-CHAIRMAN FORD: Okay.

CO-CHAIRMAN WALLIS: Do you have this POD versus depth. And what matters is is the tube going to bust and presumably it busts if the flaw has a depth close to one. So what really matters is the likelihood of not detecting a flaw when the depth is big. That's the only thing that really matters. So the tail of the right hand corner there which sort of disappears; the probability of not detecting it if it's one percent or five percent makes a tremendous difference. A little difference from one at the right hand end is really what effects the safety, isn't it?

MR. SHACK: Well, a much better measure of the structural integrity is the MP curve. Because, again, the depth if it's only a deep curve over a very short portion, you know, it results in a very small leak. So it's the combination of the length and depth that is the concern. And so the MP curve gives you a more --

CO-CHAIRMAN WALLIS: Then this business about half -- 50 percent probability or the 50 percent depth, that doesn't necessarily effect leaks or anything. It doesn't effect MP much at all.

DR. MUSCARA: So.

CO-CHAIRMAN WALLIS: So there's a lot of

effort on getting nice curves when what really matters is that end of it where it's likely break, it seems.

DR. MUSCARA: Well, it depends where you're using it. If you're using it in doing an operational assessment and you're depending on detecting small flaws to get the grow rate information, you still need to know --

CO-CHAIRMAN WALLIS: You still need that?

DR. MUSCARA: Right.

CO-CHAIRMAN WALLIS: Okay.

DR. MUSCARA: Did you say that it's a matter of a gauge that when you look at MRPC -- a value of MRPC of 2.3 corresponds to a tube failing at three times ⌂p?

CO-CHAIRMAN WALLIS: Right.

DR. MUSCARA: So, you know, anything below 2.3 it will not fail under any realistic conditions.

CO-CHAIRMAN FORD: Okay. Do you suggest we move on. We would like to close this particular session right about quarter past 12:00.

MS. LUND: I think we're start. I'm Louise Lund. I'm the section chief of the steam generator integrity and chemical engineering section in the Office of Nuclear Reactor Regulation.

This is kind of a little shift, because you're no longer going to be hearing about the research results, but people over at the regulatory side. So I just wanted to kind of set the stage there.

I also wanted to recognize Ken Karwoski is also the senior level advisor for the steam generator workover in NRR. And he's here also to answer questions and help with this presentation.

I'm going to be covering two on the steam generator actio plan items 3.7 and 3.8.

And also I think we need to kind of get a little more tightly focused, too, in that the discussions I'm going to have are relative to the plants that are implementing the Generic Letter 95-05, the voltage based criteria. And these two particular items are specific to things that came up and were discussed in the NUREG by the Committee on two different items for Generic Letter 95-05.

The first one, 3.7, has assessed the need for better leakage correlations as a function of voltage. Actually, let me page down here. Okay.

Assess the need for better leakage

correlations as a function of voltage for 7/8-inch steam generator tubes.

CO-CHAIRMAN WALLIS: Voltage -- excuse me. There is no leak because of voltage. The voltage is what's measured on some standard coil --

MS. LUND: Right.

CO-CHAIRMAN WALLIS: -- in some standard situation excited in a standard way.

MS. LUND: Right. And I also wanted to kind of set the stage, too, in that for this particular correlation for the 95-05 plants there are seven plants that are currently licensed to implement this. And five of them actually are currently implementing it; this is for the 7/8-inch tubes. Okay. There are seven plants licensed to implement, and five are currently implementing.

And in three years there's going to be two plants of this population that are going to be replacing. So after three years from now, there's only going to be five plants that are actually going to be licensed to have the 7/8-inch tubes to implement the Generic Letter 95-05 methodology.

In NUREG-1740 the ACRS Ad Hoc Subcommittee had concluded that the leakage correlation used for the voltage-based alternative repair criteria, the 95-05, for the 7/8-inch diameter steam generator tubes was poor. And in addition, they said that the Committee could identify for mechanistic reasons why data for the 7/8-inch tubes should so poorly relate to the correlations achieved with the data for the 3/4-inch tubes. And went on to say that the lack of the relationship may reflect the scatter and the limited size in the database. Because as I was mentioning, there is not a lot of plants that are actually implementing this.

The database for the 3/4-inch tubes exhibited a better correlation.

And separate correlations do exist for the 3/4-inch and 7/8-inch databases, and both databases exhibit some level of scatter. The 3/4-inch leakage database contains 48 data points. And the 7/8-inch leakage database contains 31 data points.

CO-CHAIRMAN WALLIS: Tell me something about what you mean by these correlations.

MS. LUND: Yes.

CO-CHAIRMAN WALLIS: Somebody took data about tubes that were leaking and looked at the voltages --

MS. LUND: Right. Right. Because --

CO-CHAIRMAN WALLIS: But they were only tubes which leaked?

MS. LUND: Right. As far as what databases they're putting it into, when they take the tube -- they remove the tube and they test it.

CO-CHAIRMAN WALLIS: Was it leaking?

MS. LUND: If it leaks during the test that they perform, then it's put into this leakage database.

CO-CHAIRMAN WALLIS: And then they look at the voltage that went with the leak?

MS. LUND: Right.

CO-CHAIRMAN WALLIS: And then it doesn't take any account of the same voltage having been measured on many tubes which did not leak?

MS. LUND: Well, they also have that in the database.

CO-CHAIRMAN WALLIS: Have that as well.

MS. LUND: But as far as the correlation, you're going to want to see in a correlation if I have this much voltage I'm going to expect this much leakage.

CO-CHAIRMAN WALLIS: But that's the whole point. I mean, if you only look at leaking tubes, what's --

MS. LUND: But they're looking at -- I mean the database itself, you know, has that information for the tubes that leak as well as tubes that don't leak. But as far as developing your correlation, you're also going to want -- what's of interest to you is what tubes are actually going to exhibit leakage for a certain amount of voltage.

Do you want to say anything, Ken?

MR. KARWOSKI: No, I think you're on the right -- the methodology is basically there's a database that says what is the probability that a certain voltage will leak.

CO-CHAIRMAN WALLIS: That's what you want to get?

MR. KARWOSKI: Right.

CO-CHAIRMAN WALLIS: That's what you want to get?

MR. KARWOSKI: Right. And so we have that piece. When the ACRS reviewed that a couple of years ago, they didn't have a concern with that database. But then the question became once the indication leaked and you tried to correlate that leakage to a specific voltage, for the 7/8-inch database there was a lot of scatter. So that's why-

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CO-CHAIRMAN WALLIS: So it's a very different question. Because I would think there would be many tubes which don't leak at all, even though they have quite a voltage.

MR. KARWOSKI: Right. And there is --

CO-CHAIRMAN WALLIS: But they wouldn't be in this second database, which would only look at the leakers and see what kind of voltage they have?

MR. KARWOSKI: Yes.

CO-CHAIRMAN WALLIS: It's a very different question.

MR. KARWOSKI: Yes.

CO-CHAIRMAN WALLIS: And that's why it's such a skimpy small database, is it?

MS. LUND: Right.

CO-CHAIRMAN WALLIS: Because there weren't many leakers?

MR. KARWOSKI: Yes. The probability of leakage database would have more like 130 data points versus --

CO-CHAIRMAN WALLIS: Still not very many.

MS. LUND: Right. And also realize, too, that database, in the 3/4-inch database 25 of them are from domestic pulled tubes and for the 7/8-inch database nine of these database points are from domestic pulled tubes.

CO-CHAIRMAN WALLIS: Excuse me. When these guys do what we heard about in the previous presentation, they stick this thing up the tube --

MS. LUND: The eddy current probe.

CO-CHAIRMAN WALLIS: -- and they get some voltages.

MS. LUND: Yes.

CO-CHAIRMAN WALLIS: Don't they get lots of voltages which are in this range that you're talking about here? Does the voltage quite often go, at least in the Argonne experiments, up into this range you're interested in or above six or whatever it is? I don't know what the range is.

MS. LUND: Right. This information is from tubes that they're pulling and they're actually testing in a lab, okay. They can measure the leakage from these tubes. So these are actually from pulled tube data.

CO-CHAIRMAN WALLIS: Well, I guess since you're not showing me any numbers in data, I don't quite know what I'm looking at here.

None of the Argonne tests leaked, did

they? You looked at zillions of flaws and found out if you could detect them, and none of them leaked.

DR. KUPPERMAN: Four -- we had four leakers.

CO-CHAIRMAN WALLIS: There were four leakers?

DR. KUPPERMAN: Yes.

CO-CHAIRMAN WALLIS: So what voltage are we talking about here? What range of voltage are you concerned with for leakers?

I thought you showed us this -- there's a correlation between voltage and depth, that's what the message was this morning; that there's little correlation between depth of crack and voltage.

MS. LUND: Right. But we're not correlating --

CO-CHAIRMAN WALLIS: Why are you correlating something --

MS. LUND: We're not correlating this with depth. We're actually correlating this with a probability of leakage or a probability of burst is what we're correlating it with.

CO-CHAIRMAN WALLIS: So there's no correlation then between depth and burst?

MS. LUND: Right. We're not trying to

correlate it with depth.

CO-CHAIRMAN WALLIS: That's very strange. But that's probably why it doesn't work very well. Okay. I have difficulty with this altogether.

CO-CHAIRMAN WALLIS: They got a leakage of this eight -- they got a voltage of eight and it didn't burst. But it didn't even go 60 percent through walls. It's not going to leak. So why correlate with something that there's no leakage at all? It doesn't make any sense.

MS. LUND: You know, part of the topical that describes this has this information, this data in bins where, you know, it'll go from like one volt, zero to one volt, one volt to two volts, two volts -- for the 3/4-inch and for the 7/8-inch tubes. And we'll show how many leakers they have at each voltage.

In fact, I think in that database for the 7/8-inch tubes, I think they didn't have any that leaked under two volts. Is that the kind of information you were looking for?

CO-CHAIRMAN WALLIS: Well, maybe.

CO-CHAIRMAN FORD: I guess the frustration here is even if you look at the report, the 3.7 --

MS. LUND: Right.

CO-CHAIRMAN FORD: There's no data.

CO-CHAIRMAN WALLIS: There's no figures or anything.

CO-CHAIRMAN FORD: So we're trying to work out, you know, when you're saying a lack of correlation what's the data which has not been correlated? Is it leak rate versus voltage? There's no correlation with the 7/8-inch tubes where there is for the 3/4-inch? What is the relationship for which there is no apparent correlation?

MS. LUND: Well, this is the probability of leakage and probability of burst correlations with voltage. That's the two correlations we have.

It looks like Ken wants to say something.

MR. KARWOSKI: But to specifically answer your question, the correlation which we're talking about, the correlation is weak, is the correlation of leak rate to the bobbin voltage.

MS. LUND: Right.

CO-CHAIRMAN FORD: Right.

MR. KARWOSKI: So that is the specific issue that we're trying to address.

With respect to the data, all the data was presented to the Committee two years ago and that's why the report, basically, just addresses the technical issue.

CO-CHAIRMAN FORD: Okay.

MR. KARWOSKI: It doesn't get back into here is all the data. I mean, we have numerous reports where all the data is shown again and you can look at it and see that --

CO-CHAIRMAN FORD: But i guess what's frustrating here is that we have just learned that there is no fundamental physical relationship between voltage and crack depth. And therefore, why should you would expect it therefore to be a relationship between voltage and leak rate?

MR. KARWOSKI: I guess we've known that the industry has had a curve similar to what you saw this morning since the early 1990s. We knew that voltage did not correlate to depth. If it did, the industry probably would have just made a proposal to voltage size -- to size the cracks with the voltage and apply a depth base repair criteria.

CO-CHAIRMAN FORD: Yes.

MR. KARWOSKI: What the industry decided to do was correlate voltage to the structural integrity, the burst pressure of the tube and also to leakage integrity. With that there is scatter in these databases, just like with any database, there is scatter in the data. So a given voltage you have a probability of leaking. You may test a 3 volt flaw. Fifty percent of the time it may leak, 50 percent of the time it may not leak. And that fact is included in their assessment of leakage integrity.

But then the concern is, is once it does leak, how much will it leak? And that's the issue we're talking about here is because the correlation for the 7/8-inch tube is a little --

CO-CHAIRMAN WALLIS: Well, I guess the problem I have -- I get the impression of what Argonne is doing is they're looking at -- you measure something, you get a crack, you look at your MP, you look at the loading conditions and you decide is this crack going to grow, is it going to be a leak? So it's a physics behind why there's a leak.

I get the impression that's what correlated here is just with no physics whatsoever. You just have some leakers and some --

MR. KARWOSKI: Well, it is --

CO-CHAIRMAN WALLIS: Is that you knew nothing, you're just trying to fit some points on a plot.

MR. KARWOSKI: It is an empirical correlation between the voltage that they can measure in the field versus what they observe through the testing. It is an empirical correlation.

CO-CHAIRMAN WALLIS: Okay. There is no physics, there's no cause and effect or anything in this at all?

MR. KARWOSKI: Well, in general what the -- you know, the voltage is a measure of the amount of interference the crack -- essentially the interface that the crack will have to the eddy current. And so there is some physics, you know. But with that said, you can have a very tight crack which in general we don't observe. A very tight crack with a low voltage that could have a low burst pressure. But from field data in general, that type of crack in general doesn't exist.

CO-CHAIRMAN FORD: So the specific question that was raised in 1740 was that, okay, even given there's an empirical relationship between voltage and leak rate, why physically should there be a difference between 3/4-inch and 7/8-inch tubes?

MS. LUND: Well, why should the data look different? Why -- yes.

CO-CHAIRMAN FORD: And now you're going to tell us that?

MS. LUND: Right. And I think there are things that have been done since then, okay. And that's some of the stuff that I wanted to discuss today.

I guess the next thing, just kind of getting through this slide. I would say that our bottom line is is there's a simple explanation the differences and correlations could not be established. And I think that when we looked at this, you know, possible source of scatter are that the pre-pull voltages are used. Either the cracks may open up through the pulling process and this would lead to higher leakages, you know, actually when measured in a lab, which is a conservative thing because, you know --

CO-CHAIRMAN WALLIS: Excuse me. You don't have a simple explanation. Do you have a complex explanation?

MS. LUND: Well, we have --

CO-CHAIRMAN WALLIS: You just have a lot

of hypotheses, but no explanation?

MS. LUND: Well, one thing that we -- I think that as far as a -- one explanation or one thing that has been done since then is removing the French data. And actually the next slide gets into that.

CO-CHAIRMAN FORD: I'm sorry. Before you confuse us more.

MS. LUND: Yes.

CO-CHAIRMAN FORD: A question about the pre-pull voltages. Did I understand, therefore, that the 3/4-inch database was all done on not pulled tubes?

MS. LUND: No. No. That's not what I'm trying to say. What we're trying to say is, is that both databases exhibit scatter. 7/8-inch exhibits more scatter, but it's not because the 3/4-inch does not exhibit scatter. In fact, if you look -- and that's what I was trying to get to in the discussion I had earlier of how many plants are actually represented in the database, I think it's a small database to begin with. You know, when I was saying for the 3/4-inch database you have 25 data points -- I mean as far as the leadage data points from domestic pulled tubes and in the 7/8-inch database you have nine from the domestic pulled tubes. You know, there's about the same amount in the laboratory. Twenty-three for the 3/4-inch database from the laboratory and 7/8-inch database you had 22 from the laboratory. But that's still a relatively small data set.

And in order to try to improve the correlation, industry proposed removing the French data because they were able to show that they were from different populations. They were able to establish the statistical differences.

CO-CHAIRMAN WALLIS: So how many data points did they throw out then?

MS. LUND: As far as the French data?

CO-CHAIRMAN WALLIS: Yes.

MS. LUND: Do you -- Ken has actually the graph from that.

MR. KARWOSKI: In the leakage database there are approximately 2 data points. But those two data points --

CO-CHAIRMAN WALLIS: So there are two out of 31? Okay.

MR. KARWOSKI: Two out of 31.

CO-CHAIRMAN FORD: Okay. Now why were the French data pulled? You say it's different circumstances?

MS. LUND: Well, right. Right. In fact, that's going to be the next slide.

As far as the elimination of the French data, is they were able to establish that there was a statistical and mechanistic difference in what was contained in the French data. And we're trying to say by that is that they were -- the French data had high voltage data, so they were getting higher voltages with part through wall cracks. When you look at the U.S. data for the same voltages, they were almost all through wall. So what that infers is lower leakage for the same voltages for French data. And so you could see how that would skew the results.

CO-CHAIRMAN FORD: Well, that's only two data points out of 31.

MS. LUND: Well, it's actually --

CO-CHAIRMAN FORD: I can't imagine it would make much difference in the correlation factor.

MS. LUND: Well, as far as plant data there's two out of nine.

CO-CHAIRMAN WALLIS: But essentially these are the same plants and the same technique?

MS. LUND: Well, I think that that's probably where we probably have a lot of questions as far as how much is consistent, how they apply the voltages. You know, if there is a --

CO-CHAIRMAN FORD: When you say elimination of two data points from the French, how much did that improve the correlation factor?

MS. LUND: Well, that did improve the correlation.

CO-CHAIRMAN FORD: It did?

MS. LUND: It did improve the correlation.

CO-CHAIRMAN FORD: By how much?

MS. LUND: Do you have a --

MR. KARWOSKI: It would be in terms of like a p value of the probability of having no slope. I could look up the exact value and get that to you on the break. It depends on the database you're looking at. Well, I found it.

The p value with all the data is 3.5 percent, okay? With the EDF data removed that reduces it to .9 percent. But I think the key point is there was one extreme data point that the EDF data had very high voltage indication which leaked very little. And by removing that, you greatly improve the correlation.

MEMBER SIEBER: Do you think that was just an error or a different kind of a probe or no thinking at all?

MR. KARWOSKI: We could not identify a specific error. If there was a specific error, it would have just been eliminated based on that. We only have -- we do not have an exact --

CO-CHAIRMAN WALLIS: It didn't leak at all?

MR. KARWOSKI: What's that?

CO-CHAIRMAN WALLIS: It didn't leak at all?

MR. KARWOSKI: It did leak.

CO-CHAIRMAN WALLIS: It did leak, but not very much?

MEMBER SIEBER: Right.

CO-CHAIRMAN WALLIS: But Argonne showed us this morning that there's a nice one that has a huge voltage of 8 and didn't even crack half -- it c cracked way through the tube. So it can happen that you have a high voltage and no leak. So you can have a high voltage and a small leak. It's quite reasonable. Why throw it out?

MR. KARWOSKI: When you look at all the

French data together, you do statistical analysis, there is a statistical -- no, no. There's more French data than just the tube. We're specifically talking about the leakage here.

When you look at the French data --

CO-CHAIRMAN WALLIS: But you see my problem here, right? You're throwing out something which has a high voltage and a small leak because you don't like it and Argonne has data which showed us this morning high voltage with no leak at all, which is even more extreme. Now, you see what I mean, the problem I have? A small leak and no leak at all are kind of similar. But no leak at all is even further a deviation from the correlation.

MR. KARWOSKI: But it's inconsistent with the industry database.

CO-CHAIRMAN WALLIS: Okay. Well --

MR. KARWOSKI: It's inconsistent with the industry database.

CO-CHAIRMAN WALLIS: Okay. When you get to the summary slide, we'll see what we see.

MEMBER SIEBER: Actually the correlation between voltage and what kind of characterized indication you have, you know a given voltage could result from a whole bunch of different flaw characteristics, some of which would leak and some of which would not. And so I don't see that it's inconsistent for you to report these kinds of results.

The philosophical question becomes should you use all these correlations to be able to come to a conclusion as to whether the steam generator will leak or not leak in a given amount of time. And, you know, this has been argued for years, I guess.

MR. KARWOSKI: Longer than that, but we'll take the --

MEMBER SIEBER: Well, that's when progress started to be made.

MS. LUND: Well, this is also an issue that over time is probably going to become less and less of a concern as plants are replacing. Because, as I was trying to indicate earlier, there's fewer and fewer plants implementing this as time progresses and it's going to continue in that direction.

CO-CHAIRMAN FORD: Well, you're correct factually by saying it could become a decreasing problem in this country. But it still means that there's an uncertainly out there as to something physically is occurring in these tubes that you can't explain. And therefore, it could be coincidentally, it could also be applied to the 3/4-inch tubes.

MS. LUND: Right.

CO-CHAIRMAN FORD: You don't understand what the physics are of this particular phenomena.

MS. LUND: Right.

CO-CHAIRMAN FORD: And that's what would worry me.

MS. LUND: And I think also with the 3/4-inch tubes, there's only two plants that are implementing the 95-05 criteria. So as far as -- one obvious explanation as far as how the data that's added to the database either make the correlation or make the correlation worse, and so when you have that few plants are actually implementing the criteria, you're not going to get a lot more additional data because you know, as they implement the criteria they're required to pull tubes along the way.

MEMBER SIEBER: That's where your data comes from.

MS. LUND: Exactly. Exactly. So that's also, you know, a factor in this also is that, you know, it's not an area where you're going to get, at least from field data from the plants that are implementing this, a tremendous amount of data to resolve the issue one way or another.

MEMBER KRESS: When you make the measurement of leakage, you impose a certain ⌂p across it and that comes from the tech specs?

MS. LUND: Right. It's the 1.4 main steamline break.

MEMBER KRESS: Yes.

MS. LUND: Right.

MEMBER KRESS: So you're imposing a fixed ⌂p on a tube that is already exhibiting leakage. You know it leaked before you pulled it and put it in the --

MS. LUND: No. Actually what they do is that they look at the flaws that are most significant, and that's how they choose the tubes that they -- it isn't because necessarily it's leaking inservice.

MEMBER KRESS: Okay.

MS. LUND: What they do is they pick the most significant -- least significant tubes. They also try to find one that has two or more intersections of interest. So it kind of makes it worth our while to pull that particular tube.

MEMBER KRESS: And you could hypothesize physical reasons why you would get different leak rates at different voltages.

MS. LUND: Right.

MEMBER KRESS: Because voltage doesn't really characterize the pathway for the leak very well.

MS. LUND: Right. Exactly. And also when you -- go ahead.

MEMBER KRESS: And you put this pressure on it and you don't want that pressure -- ⌂p does to the pathway either. And it may do different things to the 7/8-inch tube as it does to the 3/4-inch because they have different morphologies to the cracks and different effects.

So I could see how you could hypothesize these things and develop a mechanistic model, but it probably wouldn't be worthwhile because you just measure the leak rate versus voltage and --

MEMBER SIEBER: It seems to me you measure the leak rate on the stub that you pull out over the steam generator, right? Once you pull it out --

MEMBER KRESS: Oh, yes.

MEMBER SIEBER: -- you've changed everything that there is to change.

MEMBER KRESS: Oh, you definitely changed things.

MS. LUND: I was just about to say exactly the same thing you were saying. I think one of the biggest factors is, is that for -- 95-05 criteria a lot of them have gunk in the crevices that tend to make these tubes difficult to remove. Yes. So when you're taking this out it's not a matter of just like, you know, making your cut and it just slides right out. You know, I think that for some of these tubes I think there is a fair amount of force and you have to ask yourself is the crack that is there, how much did it get opened up and how much would it leak in service as versus what it leaked after it was pulled out and the crack was opened up. Obviously the leakage -- at least in my mind, I could see it being higher, and that's a conservative assessment because you're going to actually see more leakage for the same flaw that would be inservice that probably wouldn't be opened up quite as much.

MEMBER SIEBER: If you actually run the probe through a tube that you've pulled, the voltages are different, too, which if you have any faith in what he probe is supposed to tell you, you know you've changed the characteristics of the flaw.

MS. LUND: Right. And we're using pre-pulled voltages is what we're using so that --

MEMBER SIEBER: So there is no correlation to after a pulled leak rate to a pre-pulled voltage.

MS. LUND: Right.

MEMBER KRESS: But there exists an ACRS letter on this issue.

MS. LUND: Beg your pardon?

MEMBER KRESS: There is already an ACRS letter on this issue. And it goes back to '95, I guess.

MEMBER SIEBER: Yes.

MEMBER KRESS: And if I recall, the ACRS found this an acceptable procedure but didn't like the database at all. It just said you need more database before you actually can use this.

MEMBER SIEBER: Well, the procedure has some flaws in it. The question is, is it good enough with the data that you have to provide assurance of adequate protection in the operation of a steam generator that has indications in it.

MEMBER KRESS: Yes.

MS. LUND: Yes.

MEMBER SIEBER: And I could see reaching that that conclusion. That's what all this is all about.

MEMBER KRESS: Well, okay, and it's all a design basis accident.

MS. LUND: Right. Exactly.

MEMBER KRESS: So ACRS didn't like the database.

MS. LUND: Right.

MEMBER KRESS: They thought it was insufficient, but they thought it was an acceptable procedure.

MEMBER SIEBER: Yes.

MEMBER KRESS: You know, I haven't read the letter since '95, so I don't know --

MS. LUND: Yes. And it's actually the methodology has been implemented for 12 years, I mean at this point.

CO-CHAIRMAN FORD: Louise, could I ask that you move on to the last subject, 3.8.

MS. LUND: Sure.

CO-CHAIRMAN FORD: We've got the message on the 3.7.

CO-CHAIRMAN WALLIS: Well, could you look at the summary then?

MS. LUND: Sure.

CO-CHAIRMAN WALLIS: That's what we haven't got, is the bottom line. What is the bottom line of all this?

MS. LUND: Well, what the bottom line is that what we noticed since we had the NUREG from the Committee, is that we continued to evaluate the data. We saw the addition of new data in 2001, which was Beaver Valley and 2002 in Seqyoyah made the correlation worse but addition of new data in 2003 which is from Diablo Canyon made the correlation better.

You know, we also saw that as far as the deletion of the French data, that made the correlation better. But I think our conclusion really is more what we were just discussing , which is that we still feel that the leakage methodology is acceptable because Generic Letter 95-05 specifies more than just using information -- it specifies necessary actions in the leak rate calculation when the correlation is weak and it specifies how to account for the uncertainty in the correlation.

So even if you end up in a situation

where you have no correlation, it doesn't lay dead in the water with nothing to do. Okay. I think that the way that this -- go ahead.

CO-CHAIRMAN WALLIS: This is the problem that I have with this whole presentation: I mean there's all this stuff about correlation and numbers of tubes and so on. But the bottom line is a report I couldn't understand it at all. Everything is pretty largely methodology except because of something else, and that didn't help me at all. I mean, "this something else" is all this specifies how to account for uncertainty. That's not part of the pervious discussion, so correlation hasn't been improved, the concerns of ACRS are still there. But there's something else you do that makes it all right?

MS. LUND: Well, as far as what the Generic Letter specifies that the utility must do when you don't have a good correlation. There is something in there that the staff has found acceptable in the place of having an appropriate correlation.

CO-CHAIRMAN WALLIS: What you're saying is that we had a concern about this correlation. And it doesn't really matter because decisions are not based on that correlation anyway. There is something else that comes into play, so we should forget it?

MS. LUND: Well, no, I --

CO-CHAIRMAN WALLIS: Is that what you suggest?

MS. LUND: No. I wouldn't summarize it like that. But I think that at least from our perspective in looking at this in the last couple of years there have been things that have improved the correlation, things that have not improved the correlation. I guess, in looking at how to better improve the correlation I think that there is so many different factors that kind of work against you as far as being able to improve the correlation.

I think it comes back to what we were saying earlier as far as is there a simpler or even a complex explanation for it that we can do something different than what has already been improved and how well -- you know, the question is is how this actually being implemented in the field and whether it seems to be working in the field.

MEMBER SIEBER: The question is really a matter of margin. You know, if you make the voltage low enough at which you have to do something, then of course you can have the lousiest correlation in the world and you will end up doing something for every indication. And so if you realistically set the margin to recognize the uncertainty in the correlations, then you can still establish adequate protection, which is where I think is where we're at.

You notice that the little blips in the process that some licensee will come in and say, gee, I have this wonderful database for my plant and these steam generators and I would like to raise the voltage at which the alternate repair criteria applies. And some have it and some don't. It depends on the quality of the correlation for that plant, those steam generators.

MS. LUND: Right. Because many, many plants are just implementing it for essentially a two volt criteria. So in that range, I would agree with that, that that's --

MEMBER SIEBER: There's tons of margin.

MS. LUND: There's tons of margin.

CO-CHAIRMAN WALLIS: Now you get to the next page and its overall methodology for determining the amount of leakage and assessing its consequences is conservative. There's absolutely nothing in anything I've heard. I just maybe didn't get the information. I read what was sent to me.

There's no evidence there to tell me anything about conservativeness of the overall methodology, so there's no way I can believe or not believe this conclusion.

MS. LUND: Well, as far as the -- I think that what we were referring to in this particular sentence is how the voltages and the leakages are determined, basically the pre-pull voltage and the leakage that was assessed after the tube was pulled.

As far as how it is conservative, I think what we just discussed also and the fact that there is a limitation to the voltages in which they're licensed to use it for.

CO-CHAIRMAN WALLIS: They stick this probe up the tube, and they figure the voltage bigger than a certain amount it, they have to replace it or plug it; is that what you're saying?

MS. LUND: They plug the tube.

MR. KARWOSKI: They're plugging it, yes.

CO-CHAIRMAN WALLIS: And you're saying that it's conservative because it's highly unlikely that they would not detect something and that a tube leaked significantly; that's what the conclusion is, presumably?

MR. KARWOSKI: No.

MS. LUND: Go ahead.

CO-CHAIRMAN WALLIS: Well, I didn't see that followed from anything we saw or heard.

MR. KARWOSKI: Okay. I guess it wasn't our intent to come back and reproduce the entire methodology. That would take a day in and of itself. Our intent was to focus on the specific comment by the ACRS with respect --

CO-CHAIRMAN WALLIS: And my conclusion there is there's been just really no improvement in correlation?

MR. KARWOSKI: There has been no drastic improvement with the addition of data. We don't have a simple or a complex --

CO-CHAIRMAN WALLIS: So it's still something that might worry you, but you're still thinking the methodology's okay. That's the bottom line?

MR. KARWOSKI: That's right. The methodology accounts for the scatter in the correlation. So we do not see a safety issue associated with the use of that correlation.

MEMBER SIEBER: So nothing has changed?

MS. LUND: Dramatically.

MEMBER SIEBER: Yes. In what, the last two years, whenever it was we heard the --

MS. LUND: Right. Right. You know, because I think that one idea would be you add more data in all of it and it improves it.

MEMBER SIEBER: It's supposed to get better?

MS. LUND: But that hasn't been the case. So that hasn't been kind of a simple solution.

CO-CHAIRMAN WALLIS: Well, the problem I have is that you want me to sign off that you've addressed this issue and resolved it in some way. Well, I have absolutely no basis for making any decision. I mean, the arguments are so waffling that there's no basis for me -- and if you say I got to take two days reading your whole methodology, well maybe that's what's required, but you didn't present any of it. So I have no basis for deciding whether you've done an adequate job or not.

MR. KARWOSKI: It wasn't our intent to come here, like I said, it would have taken another -- we assumed that the ACRS having reviewed this two years ago in the context of the differing professional opinion, that we could focus on the issues that were raised. And I guess what the staff is saying is that we don't have a simple explanation for why. There is scattering of database. But the overall methodology for assessing whether or not a plant is safe, how much a tube will leak we believe that we're providing conservative estimates of the amount of leakage during a steamline break. And from that perspective, although we will continue to evaluate data as it comes in, whether or not it changes the correlation or not, we believe we have an adequate safety basis by which to go forward.

MEMBER SIEBER: Actually, there isn't much progress you could make because the data is the data and it's generated by industry based on things that happen in their plants. And it hasn't changed much. And so our -- when we complain about the adequacy of the database and you look at it for several years and say, well, the data hasn't changed much, our conclusions at the same. I guess I could sign off on that. Nothing's changed. You know, you're stuck with the data that you're stuck with.

MR. KARWOSKI: And that's basically it. The data that we have is the data that we're using.

We're not eliminating any data that we do not believe is not appropriate to eliminate. So the utility --

MEMBER SIEBER: Right. There is no issues of new data in that time frame.

MS. LUND: Right. And the expectation is not that we're going to get a lot more.

MEMBER SIEBER: Right.

MS. LUND: So that is kind of a quandary that we're in.

CO-CHAIRMAN WALLIS: So the real way to convince us would be to say we're to focus on this overall methodology and say no matter what all this lousy correlation is, we've got a method which is conservative. That's where the focus has to be. Therefore, you don't have to worry about all this, and therefore we should forget about any further studies of adding more data and correlating. But, you know, we haven't seen the arguments for that, so I don't know what we conclude.

CO-CHAIRMAN FORD: Could I suggest that we go on? I want to finish this whole subject before lunch time today. It's 20 past 12:00 now.

MS. LUND: Okay.

CO-CHAIRMAN FORD: Can you hit the

highlights on item 3.8.

MS. LUND: Sure. This one was to develop a program to monitor the prediction of flaw growth from systematic deviations from expectations. And basically the Committee had stated that the flaw growth was inherently nonlinear and occasionally individual flaws can violate even the most conservative linear bounds.

Of more concern would be a systematic violation of the linear bounding of the growth process. And I guess our answer for that is that we don't postulate individual flaw growth rates. We have a distribution of growth rates that we expect to observe based on the previous cycle. And that's part of that operational assessment that Joe was referring to earlier.

So let me just page down. So when we look at this it relates to the growth of the flaws in the steam generator tubes that are allowed to remain inservice under the voltage based alternate repair criteria, the beginning of cycle and then looking at the end of cycle predictions and see how well they're predicted. And so we ask ourselves how well is the flaw growth predicted by the methodology.

And so the focus of this was a message to the staff to be vigilant in monitoring the implementation of the alternate repair criteria to look for these systematic errors in the flaw growth predictions. So that was the intent of this particular item.

And currently, as I was saying earlier, there are nine plants that are authorized to implement this alternate repair criteria. Seven are currently implementing it. Three that implement it now we'll be replacing.

So, it's the staff's position that it's important to conservatively project the condition of the steam generator tubes, and that's been our focus.

Looking at the projections, obviously we agree with the committee that flaw growth is not linear and flaws can slowly grow until they interlink. And once they do interlink it's possible for the flaws to grow quickly. So these projections that they're making consider these three items, which is the POD which we've discussed earlier, flaw growth, NDE adjustment. And it's important to look at the population rather than the individual flaws.

So as far as the methodology, we compare the actual burst probability and leakage to the projected burst probability and leakage.

If it's nonconservative and we investigate it, we've had a couple of cases in the --

CO-CHAIRMAN WALLIS: I don't understand. I'm sorry.

MS. LUND: Beg your pardon?

CO-CHAIRMAN WALLIS: I want to get lunch, but what you said there's a problem with flaw growth prediction, the methodology is not very good for predicting flaw growth. Isn't that what we're talking about? How can you predict these burst probabilities based on poor flaw growth model? The issue is the flow growth model itself, isn't it?

MS. LUND: Well, what we look at is to see if we have deviations from expectations in the flaw growth methodology. And the --

CO-CHAIRMAN WALLIS: But you just predicted, so you can't have a deviation without a data of some sort. I don't understand.

MS. LUND: I don't understand your question.

CO-CHAIRMAN WALLIS: Well, these deviations for predictions are an actual burst probability or what?

MS. LUND: These are the predictions are far as the voltages, the beginning of cycle voltages and the end of cycle voltages. And we're predicting the burst probability and leakage probability.

CO-CHAIRMAN WALLIS: And this has something to do with flaw growth?

MS. LUND: Right. As far as we look at the voltages from what's found during your inspection and essentially growth over a cycle.

CO-CHAIRMAN WALLIS: Okay. So you're looking at the change voltage, is what you say?

MS. LUND: Right.

CO-CHAIRMAN WALLIS: And the issue was could you predict that?

MS. LUND: Right.

CO-CHAIRMAN WALLIS: Oh, okay. So it's not -- it's not the issue then and I thought you were talking about whether you predicted the flow growth right?

MEMBER KRESS: Yes, but the burst isn't secondary because there's a correlation between --

CO-CHAIRMAN WALLIS: I know that.

MEMBER KRESS: Yes. Okay.

CO-CHAIRMAN WALLIS: But the issue is

flaw growth.

MEMBER KRESS: Right. I agree.

MS. LUND: Correct. Because the --

CO-CHAIRMAN WALLIS: We're monitoring flaw growth, that's what the issue is. And it has a consequence of bursting, that's interesting. But your program is to investigate flow growth?

MEMBER KRESS: Actually monitoring voltage growth.

MS. LUND: Right.

MEMBER SIEBER: But not to predict when it bursts.

MS. LUND: But the acceptance criteria is in the burst probability and the leakage, okay. So you're looking at the probability of burst and probability of leakage and you do have acceptance criteria that you need to stay within. So that's why we go that next step besides just growing the voltages, so to speak.

So we have had cases where we have had outliers and we have investigated them in the last couple of years. And it's not uncommon to see deviations from projections and actual, but the projects are generally conservative, but not always. And if it's not, that's when we get into the action and we have meetings and we investigate the rational for why there are deviations.

And I think over the 12 years that we've been implementing, I think there has been like a handful of these larger voltage indications than were expected. And I think, you know, that's something that certainly we investigate when this comes down. So we do follow up on this. Okay.

So in following up from this, there's been some issues that have arisen from plant specific experience. And we were discussing earlier the voltage dependent growth. And some very large voltage changes in a handful of cases, most recently the one from Diablo Canyon.

And we also looked at how projections are dependently on the POD, and especially using a .6 like we were discussing earlier throughout the voltage range. In fact, we just reviewed and approved for one cycle an alternative to using .6 POD, which is POPCD. And that acronym is based on the probability of prior cycle detection, which this was approved on one cycle basis for Diablo Canyon.

The reason why --

CO-CHAIRMAN FORD: Essentially what you're doing, if I understand it, you find ah heck, the thing has gone further than I thought it would. So I'll just go back and revise my POD for the prior cycle. But there's no physical reason for doing that?

MS. LUND: There's no physical reason for using a .6 POD across. That's what I would say is that if you look at the data there is, in fact what was presented earlier, it's obvious that the POD curves don't look like a straight line of .6.

CO-CHAIRMAN FORD: That's true.

MS. LUND: And actually, we've had something in house, actually I would say four -- maybe more years. This POPCD really isn't a new idea inasmuch as the industry has looked at different probability of detection curves and more closely represent what they see in the field. And that's where this has actually come out. It wasn't just a matter of, you know, boy my data just didn't come out right and I need to very quickly develop a POD curve that I like and implement it. That really wasn't the rational for --

CO-CHAIRMAN FORD: So why didn't you just go straight to a POD versus voltage correlation that was being developed?

MS. LUND: Well, there's a POD versus

voltage. What they did is they took their plant specific data from the past, I think it's five outages, is that correct? And they put together a POD curve.

CO-CHAIRMAN WALLIS: Is the title of the subject wrong? I mean, the program is to monitor the prediction of flow growth. So what I expect is here is our prediction of flow growth and this is what we observed in flow growth.

MS. LUND: Right. Right.

CO-CHAIRMAN WALLIS: And all this other stuff --

MS. LUND: And that is --

CO-CHAIRMAN WALLIS: Why are you bringing in all these other things and POD has nothing to do with the flaw growth. It's a question of whether you detected it. Once you detected it, how does it grow; that's the only question that seems to be the subject of the title. It's all very peculiar.

MS. LUND: Do you want to go for that?

MR. KARWOSKI: If I could.

When we say flaw growth, we do not predict on a flaw-by-flaw basis what the growth rate of that flaw will be. What we say is we have a distribution of growth rates because we recognize different flaws can grow at different rates from whatever factors. So we have a distribution of growth rates that we apply to what we find during the course of the inspection.

Then when we do our next inspection we will find a different distribution of flaws. Some of them will have grown. Some of them will even have voltage less than what we had left inservice before.

The reason we look at burst and leakage as one of the measures is to account for the fact that these voltages are effected by NDE uncertainty, flaw growth and also some of the fact that some of these flaws may be new indications that develop. And so that's why we look at all three portions of the end of cycle distribution, if I can call it. Because what we're really trying to access is the ability of the methodology to predict the end of cycle conditions. One of those components is growth, one of those components in NDE uncertainty, and the other component is the probability of detection.

Now, when we use the term probability of detection as we discussed with the ACRS several years ago, it's not just a probability that you detect a flaw. It also accounts for the fact that new indications can develop. So the reason we didn't go straight to the ANL curves is because that is just a probability of detection function, whereas our, let me call it "POD" accounts not only for probability of detecting and but also for the potential for new indications to develop during the course of a cycle.

And so this POPCD accounts for two factors, whereas the ANL probability detection curves are true probability of detection curves.

DR. MUSCARA: Can I make a few comments which maybe clarify some of this?

You know, the question about back when we were referring the DPO issues and Professor Ballinger was a consultant to the Committee, the observation that was made is that crack growth rates are not linear with time while in fact the voltage growth rates seem to be. So there was a disconnect and the comments from ACRS were this is curious. Why is voltage growth rate linear while crack growth rate is not linear.

In this issue, when we keep talking about crack growth rate or flaw growth rate, and the voltage does not measure crack size, therefore it cannot measure crack growth.

CO-CHAIRMAN WALLIS: It doesn't. Right.

DR. MUSCARA: So the entire problem is the voltage growth rate is linear. Why is it linear? Because it doesn't relate to crack size. So crack growth rate is nonlinear and it should be nonlinear --

CO-CHAIRMAN WALLIS: The voltage growth rate is linear; you have a whole slue of voltages and the curves it goes up with time.

DR. MUSCARA: Right. And the voltage versus voltage rate -- I'm sorry. Voltage rate seems to be linear with time. But crack growth rate is not. But I don't see a disconnect there. I mean, that's fine because voltage doesn't relate to crack size.

MR. KARWOSKI: And so we're looking at --

MEMBER SIEBER: Voltage is an indication of the volume of material that you have. How the cracks are put together and how tight they are is another function, which is accounted for in the correlation between leakage and voltage and the probability of failure.

DR. MUSCARA: You've seen the data where you know a half of volt could have been a through wall crack as well as six volt could have been a through wall crack. And in addition, we've had flaws that are two volt and don't leak at all under steamline break pressure.

CO-CHAIRMAN WALLIS: But what does POD have to do with it? My question is, and given the POD that you have, how does the things that you measure get bigger with time? Isn't that the question, whether it's voltage or whatever it is? Voltage is going up with time, right?

DR. MUSCARA: Well, if you're tracking crack growth, it should go up with time. But if you're tracking voltage, there's no reason why it should be going up with time because it's effected by many, many different parameters.

CO-CHAIRMAN WALLIS: Well then how do you know the crack is growing.

DR. MUSCARA: The crack can be growing, but the voltage is still there.

CO-CHAIRMAN WALLIS: How do you know the crack is growing then?

MEMBER SIEBER: Because it does go up with time.

DR. MUSCARA: That's right.

MEMBER SIEBER: And the question is at a given point in time when you recognize it, should you have detected it before? And if you didn't, you can't measure the crack growth rate. And if you can't do that, you can't tell what's going the condition is going to be like at the end of the next cycle.

MS. LUND: The cycle. That's right.

DR. MUSCARA: But you can measure the voltage growth rate and then relate that back to the probability -- burst and the leak rate which is --

CO-CHAIRMAN WALLIS: The probability of growth rate is what for -- I don't understand that measure, either. This is --

MR. KARWOSKI: The change in voltage from one cycle to the next.

CO-CHAIRMAN WALLIS: Well, you run this thing up there and then you say you got some cracks and you've got some peaks so that's voltage. Is that what you mean? So you have some points on a figure, right?

MS. LUND: Right.

CO-CHAIRMAN WALLIS: And when you do it later, are these points generally seem to move up?

MR. KARWOSKI: The answer is yes, generally.

DR. MUSCARA: Generally.

MR. KARWOSKI: In some cases they don't because there's uncertainty in the measurements, uncertainty in the calibrations, uncertainly the probe --

CO-CHAIRMAN WALLIS: Okay. But that's not what we're talking about. We need to be getting on to -- we haven't really seen anything about -- all this other stuff doesn't seem to address the issue: How does something grow with time, the voltage or whatever it is?

MR. KARWOSKI: Well, I think what we're trying to present is how do we monitor -- what have we observed with respect to has there been systematic deviations from expectations.

One way of looking at this --

CO-CHAIRMAN WALLIS: What's your expectation? It will grow at one percent a year or ten percent, or whatever?

MR. KARWOSKI: Each plant has its plant specific growth rate distribution or they use a bounding industry growth rate distribution. But what we do is we look at what -- and this is where it gets into why are you looking at burst and leakage.

We look at what do they project to find at the end of their next cycle? And then we compare with what they actually found to that. And one way to do it is to put two histograms side-by-side and say well in general they looked about the same, so it's okay.

Another way to do that is to actually look at well what's the probability of burst associated with the projection versus what's the probability of burst --

CO-CHAIRMAN WALLIS: Yes. Okay. So now you're giving a presentation that you should have given here. Why do we have to ask you to --

MEMBER SIEBER: The presentation, as I understand it, was to answer the question we asked.

MS. LUND: Yes.

MEMBER SIEBER: When we wrote the NUREG-1740.

MS. LUND: That's right.

MEMBER SIEBER: And we had the benefit of --

MS. LUND: Of the whole picture.

MEMBER SIEBER: -- a whole week of this

when we formulated the question.

MS. LUND: Right. Right.

MR. KARWOSKI: Right. So I guess we owe you an apology because we focused on the very specific technical issue. The elimination of the French data, the reason we didn't discuss the ACRS conclusion was that the overall methodology was acceptable.

MEMBER SIEBER: Okay.

MR. KARWOSKI: So we focused on the specific technical issue of why is there more scatter, and we basically come --

CO-CHAIRMAN WALLIS: No. This is different. Just the flow growth. That's a different subject.

MR. KARWOSKI: Different subject, but I think --

CO-CHAIRMAN WALLIS: Related to this one?

MR. KARWOSKI: All we're saying is we're focusing on a specific technical comment that was made and we're not giving you the whole picture, again because as was pointed out, it was a week long worth of presentations. It's --

DR. MUSCARA: Okay. I think the question

here was voltage growth versus crack growth. And I think the answer is, you know, we're not tracking crack growth rate, we're tracking voltage growth rate. And that can be linear while crack growth rate is nonlinear.

MS. LUND: What would you like to do?

CO-CHAIRMAN WALLIS: Lunch.

MS. LUND: That sounds good to me.

CO-CHAIRMAN FORD: I think, quite honestly, we are -- at this stage I think we should stop for lunch to give our brains a rest so that we can think. And we'll come back at quarter to 2:00 and we'll give you another ten minutes to finish off.

I think we need to do some thinking.

MS. LUND: Yes.

CO-CHAIRMAN FORD: Give us some thought time.

CO-CHAIRMAN WALLIS: Yes, we're not getting anywhere. I'm not sure we're going to get anywhere.

CO-CHAIRMAN FORD: Well, we may not. We may not get anywhere. But let's just have five or ten minutes, start at quarter of 2:00.

So we're in recess until quarter of

2:00.

(Whereupon, at 12:40 p.m. the Joint Meeting was adjourned until 1:50 p.m.)

A-F-T-E-R-N-O-0-N S-E-S-S-I-O-N

1:50 p.m.

CO-CHAIRMAN FORD: I'd like to come back into session. We are missing a couple of Committee members, but I think we're all right as far as a quorum is concerned.

Just before we broke up for lunch I asked Ken and Louise to just give us a very short tutorial, which hopefully will relieve our concerns as to whether there are any safety concerns relating to the questions we had just before lunch on items 3.7 and 3.8.

So, Ken, if you could just give us a very short tutorial, I'd appreciate it.

MR. KARWOSKI: Okay. We'll try to go through this -- I'm going to try to go through this quickly, just to give you a context of the leak rate methodology and where the leak rate correlation fits into the overall methodology. This is just a pictorial of how you go about calculating the leakage at the end of the cycle.

CO-CHAIRMAN FORD: Right.

MR. KARWOSKI: And that's really of concern for the safety perspective. Is it will a tube burst is one concern, you know the structural integrity concern and then the other concern is will the tubes leak and how much will they leak and is that leakage acceptable.

This cartoon basically shows that you use three different distributions in order to determine the amount of leakage under steamline break conditions. This picture here is to represent the end of cycle voltage distribution. It's what you project that you're going to have in service at the end of a cycle. And that's based on growth rate, probability detection. But let's just say that this is what you project that you're going to have at end of cycle.

You then say, okay, if I have so many indications with certain voltages, what's the probability of any one of these voltages leaking? So I have a probability of leak correlation. And it looks similar to a probability of detection, you know, it's the same kind of curve --

CO-CHAIRMAN WALLIS: That's a very funny curve, the probability of no voltage is zero. I see the probability of no voltage -- oh, I see. This is standard voltage or something? What's the voltage when there's no flaw?

MR. KARWOSKI: In this picture it would

be zero. If there's no flaw --

CO-CHAIRMAN WALLIS: So the probability of no flaw is zero?

MR. KARWOSKI: No, this is not a probability. This is the probability --

CO-CHAIRMAN WALLIS: Okay. Now that's what you actually detect. Okay.

MR. KARWOSKI: Yes. If you detect a flaw of a certain voltage, what is the probability that it would leak? There's databases, hundred some data points for each of these databases. And you can come to this curve and say and say if I have a ten volt indication, what is the probability it will leak? Let's assume in one sample it says that there's a high probability it'll leak. Then you use a correlation to say how much will it leak. And you go through all the indications and sum the leakage and then you determination the amount of leakage during the steamline break.

When we presented the leak rate correlations when we were discussing the differing professional opinion, we threw up several curves that looked like this or presented information.

Ignore this. I tried to do some of these viewgraphs as fast as I could. Some of the scales are different, but I just want to illustrate point.

This is the 3/4-inch database. You see there's scatter here. Okay. This is the leak rate at steamline break conditions as a function of voltage. Okay. What it's saying is that ten volt indication may, on the average, leak somewhere around ten liters per hour or a 100 liters per hour, and there's a range to it.

CO-CHAIRMAN WALLIS: There's a range of about of about ten litters -- in the worse. It's pretty big.

MR. KARWOSKI: It's pretty big variation.

CO-CHAIRMAN WALLIS: It is two orders, yes.

MR. KARWOSKI: Right. This is the 3/4-inch correlation. Okay. And I apologize the scales are somewhat different. But that correlation didn't look bad when you compared this. And when you look at the statistics, the statistics say that the 3/4-inch correlation is better --

CO-CHAIRMAN WALLIS: But that's almost random numbers put on a piece of paper.

MR. KARWOSKI: And that was the concern that the ACRS had.

Look at the 7/8-inch coil. It looks like, let me just characterize it as a shotgun pattern on the page that there may not really be a correlation between the leak rate and the voltage. 7/8-inch, 3/4-inch, why the difference? That was the concern that became item 3.7; why the difference.

We didn't have an explanation back then. One of the comments was well maybe if you add more data, you will get a better correlation. What we tried to present this morning was we've added data, we've subtracted data where we thought there was a technical justification to subtract it. The correlation has gotten no better. This is, I believe, the current correlation. There may be one more data point. But this is the current correlation. There is still a lot of scatter. We can give you the insights for the reasons for this scatter, but we cannot tell you why there is --

CO-CHAIRMAN WALLIS: And where is the correlation among all those things?

MR. KARWOSKI: It would be the solid line.

CO-CHAIRMAN WALLIS: The solid line is the correlation.

MR. KARWOSKI: The rate of regression. Okay.

So that will be the correlation that's applied.

When the industry does the calculation. Okay. We can't tell you why. There's no simple or complex explanation for why the difference between the two. We can give you insights on the scatter in the database, like all they are is insights of why you may be exhibiting or observing scatter. Okay.

From a safety perspective now. Let's put our safety hats on, because that's what we're really concerned about is when we model the leak rate correlation in determining the amount of leakage, are we conservative. And what we tried to present this morning is we believe that we have modeled the uncertainty in this curve and said is there a correlation or isn't there. If there isn't a correlation, what the industry does is they would assume that the leak rat is independent of voltage. That basically if you had one volt indication, it's going to leak the same as a 100 volt indication.

CO-CHAIRMAN WALLIS: How big is that leak rate that they then assume?

MR. KARWOSKI: They model the error

around the distribution, because this is a Monte Carlo approach. They say so for a given one volt indication, sometime it may leak at a tenth of a liter per hour, sometimes it may leak as a 1,000 liters per hour in accordance with the scatter in the correlation.

So when we go and do the overall calculation of leakage under steamline break conditions, we believe that because of the conservatisms that are inherent in this curve, which I haven't discussed but there's conservatisms just in this curve in terms of the voltage measures, in terms of how we analyze leakage. We take the 95 percentile at 95 percent confidence and we say that's the amount of leakage from a given steam generator. We believe that overall methodology is conservative. And although we don't understand or cannot provide a simple or complex explanation for why this correlation is not as good as this one, we believe from a safety perspective that we have an adequate basis to continue to apply.

With that said, as we add more data to the database, we continue to monitor the correlations, we continue to assess it. It's an issue that as long as plants are implementing this repair criteria, we'll continue to evaluate the data and make sure --

CO-CHAIRMAN WALLIS: Well, a skeptic might say from the other -- if the bobbin amplitude has nothing to do with leak rates, so they shouldn't be used for any purposes in predicting leak rate.

MR. KARWOSKI: And in fact when the p value exceeds five percent, I think I got that right, when the p value is over five percent that's exactly what the industry assumes. They say that the leak rate is independent of the voltage.

CO-CHAIRMAN WALLIS: As long as it's more than two volts or something? Is there a cut off of some sort?

MR. KARWOSKI: No. Regardless. If I have a tenth of a volt indication, which is usually at the point of which we'll call a flaw, is that leak rate -- you know, the potential that I assign a ten liter power leak rate to a tenth of a volt indication is the same as a 100 volt indication. Because when that p value is at that, it's basically saying the leak rate is independent of voltage. So that's all in the methodology.

So overall from a safety perspective in determining the amount of leakage, we believe we have an adequate basis to conclude that plants are safe today. We can't provide you the explanation of why --

MEMBER BONACA: Well, I mean this is worse than the other one. It's not so much worse or the other one is not so much better. What I mean is if you trend a scale as the other one, the other one goes from .001 to 10,000.

MR. KARWOSKI: Right.

MEMBER BONACA: And you throw these two points on the left here 0.1, they come pretty close.

MR. KARWOSKI: Yes. Statistically, though, when you look at that p value statistics which is the probability of having a non-zero slope, essentially.

MEMBER BONACA: Yes.

MR. KARWOSKI: Basically you conclude that -- there is a difference.

MEMBER BONACA: There is a difference, yes.

MR. KARWOSKI: This database reflects the removal of those two French data points. We believe that there is a statistical reason and a physical insights on why there is a difference.

MEMBER BONACA: Yes. Could you put back

again the other one?

MR. KARWOSKI: Yes. Just didn't have time to put them all on the same scale.

MEMBER BONACA: So if you take out the range above nd the range below --

MS. LUND: You need a longer lunch time.

MEMBER BONACA: Let's put it back, too.

CO-CHAIRMAN WALLIS: There is a trend, though, here. There is simply no trend in the other one.

MR. KARWOSKI: And the p value reflects that. Just looking at the data points that were added, this one was added recently, this one was added since the ACRS, and then the two --

CO-CHAIRMAN WALLIS: So your variation is of three orders of magnitude? Somewhere in there you have a leak rate?

MR. KARWOSKI: Yes. In accordance with whatever the statistics are for the correlation. So you have some probability -- you basically know the regression equation, you know that the error around that --

CO-CHAIRMAN WALLIS: -- want a design of this kind of lack of predictability? I wouldn't design a building if I wasn't sure within a factor of 1,000 about how much weight the foundation would take or something. What is -- how should I take something like this?

MR. KARWOSKI: The way -- the data from the field is reflected in here, and this also includes some model or laboratory grown specimens. This is basically data from the field which indicates how much these flaws can leak as a function of voltage. And there's a wide variability for a given voltage how much a flaw will leak.

Even when you correlate it to length, you know, for through wall flaws, you see a wide range of variability. Maybe not as much as this, but there is a variation because leakage isn't just a simple function of through wall length. It's also a function of the tightness of crack and the tortuosity of the crack. In all leak rate correlation there is a lot of scatter. Maybe not as much as this, but there is the scatter.

MEMBER BONACA: But the unit is liter per hour, right?

MR. KARWOSKI: Yes.

MEMBER BONACA: So they're all tight holes?

MR. KARWOSKI: Right.

MEMBER BONACA: It's a trickle.

MR. KARWOSKI: Well, in terms of what observed in the field in general, the projections of the end of cycle distribution tend to be in this range down here. Usually plants do not find any indications over six or seven volts. There have been occasions where plants have found indications over ten, but usually that is very rare.

MS. LUND: Usually they're taken out of service.

CO-CHAIRMAN WALLIS: About the same as the scatter in the regular flow into the maple syrup buckets, liters per hour, depending on some variable, which doesn't matter very much. It scatters like that in some sort of random way.

I just don't quite know how you make any design decisions when you've got such tremendous variability?

MR. KARWOSKI: In terms of design decisions, I guess that the plants have to -- the plants have to -- how do we make a regulatory decision.

CO-CHAIRMAN WALLIS: Design for a 100 liters per hour or something, and that's it.

MR. KARWOSKI: Well, the regulatory

decision is made based on here's how much the leak rate is a function of voltage. And we believe we've modeled all the uncertainty with this correlation. And we take a conservative 95th percentile of 95 percent confidence, and we use that in assessing the adequacy for that plant to operate a full cycle between inspections. So the plants aren't taking the mean value. They're taking the 95th percentile, 95 percent confidence. They verify that that value is --

CO-CHAIRMAN WALLIS: They're taken the worst? They're taking the high leak rate then? They're taking the upper end of the distribution?

MR. KARWOSKI: The best way to explain is when you do the Monte Carlo, let's say you do a 1,000 simulations of the entire distribution. They will order those and they will take the 95th percentile, or if it's a 1,000 they'll take the 950th value at 95 percent confidence which means it's really like the 900 --

CO-CHAIRMAN WALLIS: But all these predictions are based on models. The model is lousy. So you're really playing games with something which is not a well defined game. You're running a game which is not itself well defined. So all this 95/95 is kind of illusion.

MR. KARWOSKI: No.

CO-CHAIRMAN WALLIS: Yes.

MR. KARWOSKI: Because we're modeling the uncertainty. It's just like any correlation of leakage as a function of crack length. There's scatter in that and we have to account for that scatter. We could show you plots where there's order, two orders of magnitude, even for that correlation. We've modeled that scatter. And because we have modeled that scatter, we believe that the end result under steamline break conditions is conservative.

And there's other conservativisms in addition to take the 95th percentile. This bottom voltage that's in this curve are pre-pulled voltages. We know when we pull that tube that we, I don't want to say destroy the flaw, but we distort the flaw. In general, it's going to leak more than if we had not pulled the tube out of the steam generator. We're using those pre-pulled voltages which basically means that if we're able to do a steamline break in a plant for any given indication, we would probably observe less leakage than what is recorded on here.

The other thing it doesn't take into account is the fact that the crevices between the tube and the tube support plate are packed.

There's many conservatisms in this model.

CO-CHAIRMAN WALLIS: So it's the leak rate of the ⌂p of 2,000 or something?

MR. KARWOSKI: 2560. Around there. It varies from plant-to-plant, though. There's a lot of conservatisms just in putting this data together. Part of those conservatisms lead to the scatter, the pre-pulled voltage.

CO-CHAIRMAN WALLIS: So this is your answer to why we shouldn't worry about the scatter?

MR. KARWOSKI: Right. Why we should not worry about the scatter is because we believe that the overall methodology is conservative. The methodology accounts for the fact that if there is a weak correlation, it tells the utilities how to address it. It basically says, you know, if the correlation is weak, you need to assume that the leakage is independent of voltage, which we believe is a very conservative assumption because basically you're saying a tenth of a volt indication can leak just as much as a 30 or 40 or 50 volt indication in general, whereas there may be some exceptions. In general that's going to be a very conservative assumption.

CO-CHAIRMAN FORD: Okay. And your further argument was that for burst that the -- well, you've got -- from a severe accident situation the burst scenario, there's a good deal of margin with the burst pressure?

MR. KARWOSKI: Right. Once again, here's just a plot of burst pressure versus bobbin voltage. This is for 7/8-inch tubing. The burst pressure is along the Y axis, the bobbin voltage along the X axis.

This top curve is the mean curve. That's the mean for all the data. And I'm sorry I don't have a curve -- I didn't have a curve readily away available with all the data. But that's the mean curve. Here's the lower 95 percent prediction interval. And this is the curve adjusts the lower 95 percent prediction interval adjusted for lower bound material properties.

And if you look at this it would say that an indication on the order of roughly 9 volts, or 8.8 volts it basically has adequate structure integrity. It can withstand pressures of 1.4 times the steamline break pressure, which equates to about 3600 pounds per square inch.

So an 8 volt indication has adequate integrity at 1.4 times the steamline break pressure. The repair limit where people plug all our PC confirmed indications is above 2 volts. So the repair limit, in and of itself, basically says the only thing I can leave in service is indications that are less than two volts. So then the question is, you know, what it the potential that if I left a two volt indication in service or any of these others, what is the potential that it can get up to the 9 volt range. And, in general, our operating experience indicates that even with the assumptions that we make on growth rates --

CO-CHAIRMAN WALLIS: I'm a bit puzzled, because I think we said that that curve we just saw, the leak rate was independent of voltage. But here you've got something which depends on voltage. How can you have something that depends on voltage when leak rate's independent of voltage?

MR. KARWOSKI: Because this is am empirical correlation. The burst pressure for both the 3/4-inch and 7/8-inch seems to be well correlated to the voltage --

CO-CHAIRMAN WALLIS: Well, you see my problem. And a pretty good correlation is just a straight line through the middle of all that data, flat, no effect with voltage at all. Would that makes these other curves flat down here?

MR. KARWOSKI: If the question is does this curve --

CO-CHAIRMAN WALLIS: If that straight line had been flat --

MR. KARWOSKI: Yes.

CO-CHAIRMAN WALLIS: -- instead of going up like that, would it would have been flat in the next curve that you just showed us?

MR. KARWOSKI: This is some of the same data. This is some of the same. All of this data --

CO-CHAIRMAN WALLIS: But your predictions are based on the models. They're not based on the data. The data gives the model, the model gives the predictions. But you don't get the predictions right from these data. You don't get that curve you just showed us of burst pressure versus voltage from these data.

MR. KARWOSKI: Not --

CO-CHAIRMAN WALLIS: You get it from a correlation based on the data, which is then used --

MR. KARWOSKI: It's empirical -- this line is based on this data.

CO-CHAIRMAN WALLIS: And then you use that plus some statistics about that line --

MR. KARWOSKI: No.

CO-CHAIRMAN WALLIS: -- to predict this?

MR. KARWOSKI: No, no, no, no.

CO-CHAIRMAN WALLIS: No?

MR. KARWOSKI: This is --

MS. LUND: Show him where the first one--

MR. KARWOSKI: The first pressure calls for square inch.

MEMBER KRESS: It's a separate correlation.

CO-CHAIRMAN WALLIS: Oh, it's a separate thing?

MR. KARWOSKI: It's a totally separate --

CO-CHAIRMAN WALLIS: Totally separate.

MS. LUND: Totally separate. Yes.

MR. KARWOSKI: Totally separate. Now, some of the data points --

CO-CHAIRMAN WALLIS: So what went into there had to be something that tied voltage to wall size, or something?

MR. KARWOSKI: To the burst pressure.

CO-CHAIRMAN WALLIS: Where does that come from? Do you have another plot of burst pressure versus voltage?

MR. KARWOSKI: Yes. For both 3/4-inch and 7/8-inch --

CO-CHAIRMAN WALLIS: That's what's important then. When you showed us this leak rate thing, how about a plot like that for burst -- with data?

MR. KARWOSKI: I could get it. I just didn't have a chance. The data is priority. I had this curve right away available.

CO-CHAIRMAN FORD: To defend Ken, I just asked him before lunch to come up these. But just to reassure us, Ken, there are data that support those trend lines?

MR. KARWOSKI: Yes.

CO-CHAIRMAN WALLIS: So we can forget about the leak rate because the only thing that matters is burst pressure. And you've got a better database for that?

MR. KARWOSKI: No. Both are important. We assess what is the probability of burst. We assess what the amount of leakage during steamline break conditions.

CO-CHAIRMAN WALLIS: Okay.

MR. KARWOSKI: We assess both of them.

MS. LUND: Independently.

MR. KARWOSKI: Independently.

CO-CHAIRMAN WALLIS: So you have another plot like this which is in terms of leak rate? And then you have an acceptability criterion for that?

MR. KARWOSKI: This is leak rate.

CO-CHAIRMAN WALLIS: No, the prediction. This is data correlation.

MR. KARWOSKI: Yes.

CO-CHAIRMAN WALLIS: What is the prediction like the one you just showed us for the accident leak rate, and why is that conservative?

MR. KARWOSKI: This one?

CO-CHAIRMAN WALLIS: No, with data. Not just a cartoon. With the real --

MR. KARWOSKI: I'm not sure what you mean by data.

CO-CHAIRMAN WALLIS: Well, you showed us burst pressure versus pressure.

MR. KARWOSKI: Yes.

CO-CHAIRMAN WALLIS: You said, look,

even if the voltage is so big or 95/95 it's not going to burst, right?

If you do something for leak rates, say here's leak rate versus voltage, here's our prediction, here's my 95/95 -- it's never going to leak more than so much, therefore it's acceptable.

MR. KARWOSKI: The amount of --

CO-CHAIRMAN WALLIS: You can't just draw cartoons that says you have a leak rate. You've got to put some numbers on them.

MR. KARWOSKI: Well, the numbers come from the plant specific inspections. So each plant once they do their inspections, they'll have a distribution of voltage.

CO-CHAIRMAN WALLIS: Of leak rates?

MR. KARWOSKI: What's that?

CO-CHAIRMAN WALLIS: Of leak rates.

MEMBER SIEBER: Not leak rates.

The only time a leak rate applies is after you have the steamline break. And we have not steamline breaks with defective steam generators. So there is no data at all.

CO-CHAIRMAN WALLIS: So when they do all this and they calculate the leakage, is it acceptable with this 95/95 error?

MR. KARWOSKI: Yes.

CO-CHAIRMAN WALLIS: It is. So if we simply said all leaks have a thousands per minute, that would be okay, which seems to be the upper limit of that data there, which is about the 95/95?

MR. KARWOSKI: It would depend on the plant specific inspection results and the plant specific licensing basis. Because the amount of leakage that they can tolerate depends on off-site dose concentrates.

MEMBER SIEBER: That's right.

MR. KARWOSKI: Okay. GDC 19 Part 100.

MEMBER SIEBER: Part 100.

MR. KARWOSKI: Okay. Each plant has it's own specific number. Okay. A lot of plants have 1 gallons per minute, but some plants have 10 gallons per minute, 15 gallons per minute.

CO-CHAIRMAN WALLIS: So how do we know that this uncertainty in the leak rate is acceptable?

MR. KARWOSKI: The uncertainty? What I'm saying is that when we do the calculations, when we project how much leakage we have associated with this distribution, the correlation is conservative because of how we do the testing, what voltages we're reporting. That part's conservative. In addition, we're not looking at the mean leak rate, we're looking at a 95th percentile.

Then we put it into the dose assessment, which I understand has a lot more conservatisms it in it -- I'm not -- but there's conservatisms along every step, which is an industry criticism.

CO-CHAIRMAN FORD: If I could suggest that, you know, obviously we've still got a lot more questions on this particular item, but let's table them for the time being and let's move on.

Louise, Ken, thank you very much, indeed.

MS. LUND: Okay. Thanks.

CO-CHAIRMAN FORD: I'd like to move on I think the next topic. Joe, would you like to introduce it, please?

Thank you. Thank you for putting in those extra bits of information.

And we move another simple subject.

DR. MUSCARA: We'll be talking about main steamline --

CO-CHAIRMAN WALLIS: We are looking back at 3.1, something like that.

CO-CHAIRMAN FORD: Yes, 3.1.

CO-CHAIRMAN WALLIS: I've got to get organized. Because I have it organized by number and not by what it represents.

DR. MUSCARA: We are addressing the issue of a potential propagation of large elements in the line break. And this presentation is in two parts. The first part some hydraulic work that was done to define the forces on the support plate. And that was input to a structure integrity analysis, and that will be the second presentation.

So Bill Krotiuk will provide the first part.

CO-CHAIRMAN WALLIS: We heard this the other day in some other context.

MR. KROTIUK: I presented it basically at the TRACE.

CO-CHAIRMAN WALLIS: Right.

MR. KROTIUK: Yes, a couple of people weren't there.

MEMBER SIEBER: Everybody important.

CO-CHAIRMAN WALLIS: No, it was the Thermal Hydraulic Subcommittee.

MR. KROTIUK: I'll just introduce myself. I'm Bill Krotiuk. I'm in Office of Research.

And what I'm going to basically discuss is the generation of the thermal hydraulic forces in the steam generator that occur on the tube support plates, basically, and this input would be then given to the stress analysis to take a look at the effects on the possibility of having some adverse cracking effects, ruptures of the tubes themselves.

The work was done basically on the Generic Safety Issue 188, which was in response to the action plan items 3.1a, 3.1b and 3.1c.

The outline basically is to use the TRACE code to generate these loads on the steam generator tube support plates and the tubes themselves and to perform sensitivity studies with the codes and model parameters to verify that the code is appropriate for doing this calculation. And also to compare the predictions to conservative calculations.

Specifically, in order to verify the TRACE code I did compare it to a number of tests that were related to this behavior, to this expected behavior inside the steam generator. And then performed the calculations themselves for a typical steam generator and compared it with the conservative results.

The verification effort for TRACE --

CO-CHAIRMAN WALLIS: I'm a bit puzzled here.

MR. KROTIUK: Sure.

CO-CHAIRMAN WALLIS: One of the important things happening is transient flow through these support plate, whether waves are reflected or transmitted?

MR. KROTIUK: Correct.

CO-CHAIRMAN WALLIS: And that's not an easy thing. You've got here essentially momentum balance of the sudden change of area and sudden geometry. And I noticed in your write up that TRACE doesn't include two phase pressure drop correction for irreversible form losses. And this is an area where the kind of models that are in TRACE are not good for sudden changes of area and form losses and things like that. And yet, this is a key part of the phenomena is that at a plate with holes in it, you've got some wave reflected and some goes through.

MR. KROTIUK: That's correct, yes.

CO-CHAIRMAN WALLIS: So I'm really not sure if you look at the TRACE documentation or RELAP documentation --

MR. KROTIUK: Right.

CO-CHAIRMAN WALLIS: -- that that particular situation is modeled particularly accurately.

MR. KROTIUK: But the key --

CO-CHAIRMAN WALLIS: Is this all modeled on sort of a nice type that changes area rather slowly and --

MR. KROTIUK: Yes, but the key force across the tube support plate is the differential pressure --

CO-CHAIRMAN WALLIS: Right.

MR. KROTIUK: -- from the top to the bottom.

CO-CHAIRMAN WALLIS: Right.

MR. KROTIUK: You see later on, I included the equation that I used to calculate this pressure drop or force on the tube support plate. And it is a function of the lost coefficient and the flow through the holes themselves.

The lost coefficient itself was based on some test data, and I verified that by using some information of Idelchik.

CO-CHAIRMAN WALLIS: This is just a single phase lost coefficient?

MR. KROTIUK: It's a single case lost coefficient.

CO-CHAIRMAN WALLIS: As long as it's single phase, maybe you're okay.

MR. KROTIUK: Yes.

CO-CHAIRMAN WALLIS: You do have an empirical lost coefficient.

MR. KROTIUK: Yes.

CO-CHAIRMAN WALLIS: And is that okay for unsteady flow through these holes?

MR. KROTIUK: In order to try get the effects of the unsteady flow, the exact equation that I used, which I present in a couple of viewgraphs, do include some acceleration effects.

CO-CHAIRMAN WALLIS: So you have looked at all that?

MR. KROTIUK: Yes.

CO-CHAIRMAN WALLIS: Okay.

MR. KROTIUK: If I'll just continue and I'll show that equation in a moment.

CO-CHAIRMAN WALLIS: Sure.

MEMBER RANSOM: Well, I think in their defense, that kind of model is used even for water hammer analysis in single phase fluids.

CO-CHAIRMAN WALLIS: Oh, yes. There's an

area change.

MEMBER RANSOM: But nothing is known about what the actual process used.

CO-CHAIRMAN WALLIS: But it's a multidimensional flow through --

MEMBER RANSOM: Quasi-steady.

CO-CHAIRMAN WALLIS: It's not a one dimensional thing and so on.

MR. KROTIUK: Okay.

CO-CHAIRMAN WALLIS: I think what saves you is the huge area change between the pipe and the steam generator. That really is what extenuates the wave.

DR. MUSCARA: There is a lot of entunuation to that, yes.

CO-CHAIRMAN WALLIS: Almost all of, in fact. Yes.

MR. KROTIUK: The verification effort that I started -- the verification effort included the effects of acoustic wave transmission. And, of course, it also included the transient flow phenomena and some pool swell effects.

CO-CHAIRMAN WALLIS: Now, I'm sorry. Just to get the picture.

MR. KROTIUK: Right.

CO-CHAIRMAN WALLIS: You compared it with some of experiments the LOFT and Edwards and so on, which are very simple geometry of pipes with vessels. This is a thing with tubes and support plates in it.

MR. KROTIUK: Right.

CO-CHAIRMAN WALLIS: And I don't know if we have a database for how transient effects go through that kind of a geometry.

MR. KROTIUK: I have four sets of data. Let me just go to the --

CO-CHAIRMAN WALLIS: Okay. So you do have data that looks something like the real geometry?

MR. KROTIUK: Yes. I have data for something that looks like the real geometry.

CO-CHAIRMAN WALLIS: Okay. Thank you.

MR. KROTIUK: And it happens to be a steam generator.

CO-CHAIRMAN WALLIS: That's good. That's nice. Real data and a real steam generator?

MR. KROTIUK: Yes.

CO-CHAIRMAN WALLIS: Good. Wonderful.

MR. KROTIUK: Well, not a -- well, .8 size.

CO-CHAIRMAN WALLIS: Well, that's pretty close.

MR. KROTIUK: Yes.

The first two experiments that I looked at were the typical Edwards blowdown experiment. And I didn't include the specific comparisons here, but I'll just discuss the results versus the predictions.

It's basically a subcooled water depressurization. And basically I was able to predict the results for pressure, temperature and void fracture because those were measurements. And basically it was a pipe with a rupture. And one thing I did find is that the node size had to be about equal to the pipe diameter.

CO-CHAIRMAN WALLIS: Okay. If you look at the Edwards data, what you predict is very good after the initial transient. It starts at 7 megapascals and goes down very rapidly. There must be acoustic waves in the water alone before you get any two phase effects.

MR. KROTIUK: Yes.

CO-CHAIRMAN WALLIS: And then you get a two phased transient, which you modeled very well.

MR. KROTIUK: That's right. Right.

CO-CHAIRMAN WALLIS: But the initial transient where you've got a water hammer type wave in the water alone is not modeled at all well. I don't think you ever try to. And yet that is where you get some of the big transient --

MR. KROTIUK: Two comments I have on that. One is that the LOFT test addresses that. But I remember the last time I presented this at the TRACE, when we TRACE code, I did look at that specifically. And basically what happened is, is when I plotted up the data and you had seen the results, I didn't have a close enough, a small enough pot frequency to show that information.

I did do a comparison of that and it was adequate. It didn't do a great job.

CO-CHAIRMAN WALLIS: So it leaps down to saturation almost at once?

MR. KROTIUK: Yes.

CO-CHAIRMAN WALLIS: But not quite almost at once?

MR. KROTIUK: Not quite, yes.

CO-CHAIRMAN WALLIS: And the question is, is there some transient in that first millisecond that you have to worry about?

MR. KROTIUK: It is that the Edwards

problem was so small that I think that that's not a really good problem to look at --

CO-CHAIRMAN WALLIS: I'm not even sure that they had the instrumentation to measure that?

MR. KROTIUK: Yes. Right.

I think really to look at the acoustic effects you'd have to look at the next one, which is the LOFT semiscale test. That one really produces the --

CO-CHAIRMAN WALLIS: And that's all subcooled?

MR. KROTIUK: That's all subcooled.

CO-CHAIRMAN WALLIS: Never boils at all?

MEMBER RANSOM: There was pretty good data from the Edwards pipe blowdown. I think wasn't it 8 meters long?

MR. KROTIUK: It is --

MEMBER RANSOM: And it's about 5 milliseconds for the wave to reach --

MR. KROTIUK: It's 4 meters long.

MEMBER RANSOM: Four meters long?

MR. KROTIUK: Right. And it's about 2.8 inches in diameter.

MEMBER RANSOM: Right. But the pressure data was pretty good at the backend of the pipe.

You know, there was a period where you could see the heat pressurization wave arrive.

MR. KROTIUK: Yes.

MEMBER RANSOM: And I would think the code would do a reasonable job of predicting that time.

MR. KROTIUK: In fact, I'll throw this up.

CO-CHAIRMAN WALLIS: Yes, you should show some figures.

MR. KROTIUK: I didn't include it, but I'll include it.

This was at 1.5 meters of the close down. And what you see here is the test data --

CO-CHAIRMAN WALLIS: Well, it leaps down to saturation essentially and then falls off from there.

MEMBER RANSOM: And I think the time you're talking about is very near the first 5 milliseconds.

CO-CHAIRMAN WALLIS: Right. That's right.

MR. KROTIUK: The time -- the acoustics stuff is really right here.

MEMBER RANSOM: That's right.

CO-CHAIRMAN WALLIS: But if you let down and then up again, there were some oscillations in there that could presumably --

MR. KROTIUK: Actually, when I plotted it up there was actually just one oscillation --

CO-CHAIRMAN WALLIS: There is something in there, right.

MR. KROTIUK: -- that it showed, no more than that.

CO-CHAIRMAN WALLIS: Since it's pressure differences we're concerned about, those pressure fluctuations could load something.

MR. KROTIUK: Yes. But, again, I think for the acoustic effects I'd prefer to look at the raw test rather than these.

CO-CHAIRMAN WALLIS: Okay.

MEMBER RANSOM: Well, if you want to look at the acoustic effect in water, I mean it did correspond to the 1,000 meters a second and transmission through water at the time that the pressure -- or depressurization arrived at the backend of the pipe. So you have to look in detail at that early time. And I think the codes do a reasonable job of that, provided you restrict the time step.

MR. KROTIUK: Right. That's one of the reasons when I was doing all these studies I was looking at numerical schemes and time subsizing also. And that was an important finding. In other words, what kind of numerical scheme and accuracy do you need for that --

CO-CHAIRMAN WALLIS: Well, the pressure is predicted very well. The void fraction is not particularly good, but presumably that's because it's a saturation and it doesn't really matter too much.

MR. KROTIUK: Well, the void fraction in my mind really is not too bad, because it's very hard to measure void fraction anyway from experimental data. It's following the basic trends.

Since we're talking about, to show you the data, I will throw up the LOFT data. And let me maybe go back one on this one.

The LOFT data that I got these predictions on is basically a tank. The rupture was up in this area here. And there were pressure measurements here and pressure measurements here.

I compared the trace predictions to test data and also compared it to a method of characteristic calculation, which is really more appropriate or the best method of doing the acoustic phenomena, water --type of things.

And, as you can see, what I did is I looked at different numerical schemes and tried to look at that effects.

CO-CHAIRMAN WALLIS: Now, this experiment, it took me some time to figure out what was happening. But there's an orifice, one inch diameter --

MR. KROTIUK: Right.

CO-CHAIRMAN WALLIS: And the pipe size is 416th-inch. So almost all of the pressure drop is taken right across that orifice, isn't it? You're not imposing a sudden depressurization of the pipe, because it's the orifice?

MR. KROTIUK: But there is a depressurization.

CO-CHAIRMAN WALLIS: There is some.

MR. KROTIUK: There is some depressurization. But the important thing is that what you're doing is that when they give you depressurization wave traveling back here, it's going to travel back in this direction, and it's going to reach this here and you're going to get reflections. Transmissions and reflections, and that's the important thing that you want to be able to predict.

CO-CHAIRMAN WALLIS: But it's a small fraction of the total pressure on this wave. Because if you had opened the whole pipe instead of the orifice, you've had a much bigger wave?

MR. KROTIUK: Yes. Yes, you're right. But, you know, I think this problem was --

CO-CHAIRMAN WALLIS: I'm sorry. I said that because a steamline break you actually break the whole pipe. It's not as if you have a little hole in it which is that's what you've got here.

MR. KROTIUK: Right.

CO-CHAIRMAN WALLIS: And it might be that something is different when you have these very big wave rather than just this little acoustic type of wave that you have here. That's why I brought it up.

If you wanted to simulate breaking the pipe, you'd break the pipe and not just have a little hole in it at the end.

MR. KROTIUK: Well, two things. One is that I wanted to by comparisons with this experiment be able to show that the code was able to follow the acoustic waves, and then when you're talking about the large breaks I think that they would be more appropriate to compare those with the next two experiments, which are really full pipe breaks.

MEMBER RANSOM: Well, I think too you're using the code primarily to model what goes on inside the steam generator and there you've got a lot of equipment like separators that are not modeled very well anyway, you know. And so there are simply losses within the steam generator, rather torturous paths that the acoustic wave actually goes through. So this has got to be regarded as, more or less, an average type of model of that process.

MR. KROTIUK: Yes. I think the main thing that the codes will do, and this is true either of the method characteristics or the TRACE or RELAP5 type codes is that it's going to -- it'll be effected by the area changes, you know.

MEMBER RANSOM: True.

MR. KROTIUK: That's more than the lost coefficient here. It's the area changes that --

MEMBER RANSOM: What I was getting at is there are also torturous passages that you simply can't model and so you just have to lump that in as a loss and just transmit it through that.

MR. KROTIUK: That's correct. Yes.

CO-CHAIRMAN WALLIS: Which one is P1?

MR. KROTIUK: Okay. P1 is --

CO-CHAIRMAN WALLIS: The one doesn't change very much?

MR. KROTIUK: I mean, I just choose that point. There was data, you know -- I do have P1 and I do have P2.

CO-CHAIRMAN WALLIS: Why does your presentation not have the data in it? I mean, you're very good at these transparency. I wish your handout had something like that, because without it, it's all words.

MR. KROTIUK: Yes. Okay. I was trying to limit the length of the duration.

CO-CHAIRMAN WALLIS: The Committee is more -- more satisfied to see figure like this than it is to read a lot of words.

MR. KROTIUK: Okay. I could give you these. It's not a problem.

CO-CHAIRMAN FORD: We'd really appreciate that.

MR. KROTIUK: Yes. Okay. You can have these right after I finish with them.

MEMBER RANSOM: Well, I think all the plots are in your report that was --

MR. KROTIUK: The plots are in the report. In fact, there is more plots than -- I should say that, yes, all the plots are in the report.

CO-CHAIRMAN WALLIS: Now which is the one which is like a steam generator? Is that the Westinghouse?

MR. KROTIUK: The Westinghouse, right.

CO-CHAIRMAN WALLIS: Is that in your report?

MR. KROTIUK: Oh, that one is not in the report, because that was a separate report that was given to me because the GE vessel blowdown test and the Westinghouse steam generator testing was done by ISL. So that was not in that report. Simply it wasn't completed when I did that. It is completed now.

CO-CHAIRMAN WALLIS: Well, this is much more convincing. You have some internal structure and you can show that you do it right. Is this proprietary stuff?

MR. KROTIUK: No, it's not proprietary. There is a NUREG that will be completed that will include that data.

CO-CHAIRMAN WALLIS: I think that would

be very helpful.

MR. KROTIUK: It's just not released yet.

CO-CHAIRMAN WALLIS: One of my comments was, you know, that Edwards and LOFT, these are relatively simple experiments and so you'd expect to do it right. But when you've got something with internal structure like a steam generator, there are real questions about whether or not you get a 84 percent of this wave transmitted and things like that.

MR. KROTIUK: Yes. But I could either give you a copies of those reports, which is not a problem. I don't know what your time frame is.

CO-CHAIRMAN WALLIS: Well, if we're not going to reach a conclusion yet, then you can give us more evidence.

MR. KROTIUK: Right. Okay.

CO-CHAIRMAN WALLIS: Do you have something to show us of data from these better tests?

MR. KROTIUK: Okay. I could show you, again, viewgraphs that I have here that weren't in the original.

CO-CHAIRMAN WALLIS: These are tests

with actual internal structures?

MR. KROTIUK: They are two vessel blowdown tests. And these were just vessels. There was no internal structures on this one.

CO-CHAIRMAN WALLIS: That's different. Did Westinghouse have internal structures?

MR. KROTIUK: Yes.

CO-CHAIRMAN WALLIS: That's the one I'm interested in.

MR. KROTIUK: Okay.

CO-CHAIRMAN WALLIS: We have time, Mr. Chairman, to look at some real data from something like a steam generator?

CO-CHAIRMAN FORD: Absolutely.

MR. KROTIUK: Okay.

CO-CHAIRMAN WALLIS: So this is something that's like a steam generator?

MR. KROTIUK: Yes.

CO-CHAIRMAN WALLIS: And what happens there, it's going to be much more like what happens in a main steamline break than any idealized simple task.

MR. KROTIUK: This is a scaled Westinghouse model of a steam generator.

CO-CHAIRMAN WALLIS: Yes. And they

break a pipe somewhere? Okay. So the physical model, we just assume it's something like a steam generator and they break a pipe?

MR. KROTIUK: Right.

CO-CHAIRMAN WALLIS: That's good.

MR. KROTIUK: And we looked at two tests, because they were the best data that we had and what we thought was typical of what we were looking at.

MEMBER RANSOM: Is this a model of a steam generator or full scale?

MEMBER SIEBER: It's a model.

MR. KROTIUK: It's a model. Yes.

MEMBER RANSOM: Subscale,I guess?

MR. KROTIUK: Yes. And remember the size --

CO-CHAIRMAN WALLIS: But it has internals which --

MR. KROTIUK: Excuse me?

CO-CHAIRMAN WALLIS: It has internals which have the same sort of area of holes and everything.

MR. KROTIUK: Yes. I'll show you this.

CO-CHAIRMAN WALLIS: Okay.

MR. KROTIUK: This was --

CO-CHAIRMAN WALLIS: It has fewer tubes, but this sort --

MR. KROTIUK: It has fewer tubes, but it does have tube support plates.

CO-CHAIRMAN WALLIS: And the holes, the tube supports have holes in them which are typical of -- most of the space is holes, isn't it? It's either holes for the tubes or holes for the fluid.

MR. KROTIUK: Well, there's holes for the tubes and holes --

CO-CHAIRMAN WALLIS: There's not much left for the metal. It's a pretty perforated piece of --

MR. KROTIUK: It's perforated. And so in these tests there were pressure measurements basically involved.

CO-CHAIRMAN WALLIS: Good. Differential pressures across the plates and everything?

MR. KROTIUK: Right.

CO-CHAIRMAN WALLIS: That's a much better test.

MR. KROTIUK: Some of the pressure measurements points were away from the plates, so there is some --

CO-CHAIRMAN WALLIS: Yes. And what's

being shown on the left there?

MR. KROTIUK: Oh, these are some comparisons here between code predications and data is in green.

CO-CHAIRMAN WALLIS: What's the differential pressure across?

MR. KROTIUK: This one happens to be two to three, so it shows a point --

CO-CHAIRMAN WALLIS: So it's the pressure drop across the plate?

MR. KROTIUK: Across this plate here.

CO-CHAIRMAN WALLIS: And it's not predicated all that well in time, but the amplitudes and things -- in fact, it goes down so the load is decreasing as the wave goes by?

MR. KROTIUK: This one happens to the bottom one, yes.

And then this is between 6 and 7, which is across the tubes --

CO-CHAIRMAN WALLIS: And what happens at times 60, there's sort of a vertical green line that--

MR. KROTIUK: They started their transient right there. So that's when the break the current.

CO-CHAIRMAN WALLIS: So there isn't an initial blow --

MR. KROTIUK: Surge.

CO-CHAIRMAN WALLIS: There's initial surge or something there?

MR. KROTIUK: Over here?

CO-CHAIRMAN WALLIS: Very short quick load at the beginning.

MR. KROTIUK: Right.

CO-CHAIRMAN WALLIS: Isn't that what we were talking about earlier? Something that happens very early on.

MR. KROTIUK: Yes. That's the important loading --

CO-CHAIRMAN WALLIS: Right, that sudden one. Right. You should blow that up, because the rest of it isn't so important.

Is there some detail of that?

MR. KROTIUK: I don't have the details --

CO-CHAIRMAN WALLIS: We're interested in millisecond or something, aren't we --

MEMBER SIEBER: That's right.

MR. KROTIUK: Right. You're right.

CO-CHAIRMAN WALLIS: The question is did

you predict that right. There's really data in that blip or the data not -- was the system not designed to take data over a short period of time?

MR. KROTIUK: It's really not designed to take data.

CO-CHAIRMAN WALLIS: So it really isn't testing these acoustic type waves? It doesn't add transducers with any response time?

MR. KROTIUK: No.

CO-CHAIRMAN WALLIS: So is it a good test of that initial transient?

MR. KROTIUK: This is the test that we had.

CO-CHAIRMAN WALLIS: But is it a good test of what you're interested in, that initial transient?

MR. KROTIUK: It'll give you some feeling.

CO-CHAIRMAN WALLIS: Ah. Is it a good feeling?

No, seriously, the load -- fracture pressure, it looks as if it goes to -- I don't know -- 1.7 or something.

MR. KROTIUK: Yes.

CO-CHAIRMAN WALLIS: I cannot really

tell because that green lines goes up. Isn't that the blip you're interested it? That blimp that goes up to 1.7 at 60 seconds?

MR. KROTIUK: Yes, that's the blip you're interested in.

CO-CHAIRMAN WALLIS: But that's not something they were capable of recording with their instrumentation?

MR. KROTIUK: The way I understood their instrumentation was not really fine enough to really give those readings. But it gives us a feeling of what it is.

CO-CHAIRMAN WALLIS: I don't know if it does give me feeling, because that initial transient may be governed by different phenomena than the later one. It's a very short time scale. And then there's that kind of relaxation at the system thereafter. I think it's a very nice test, but it would be very good if they had transducers that had a quick response so we could see.

And if you have a big loading for a short time, it's like water hammer. You're not really too concerned about it, because it's the impulse you're interested in.

MR. KROTIUK: Yes.

CO-CHAIRMAN WALLIS: Not the integrated load or the time.

MR. KROTIUK: You're right.

CO-CHAIRMAN WALLIS: So a measure of peak pressure isn't necessarily the right measure.

MEMBER SIEBER: But these pressure pulses either by analyses or tests are very small compared to the overall stiffness of the structure, right? They result in minuscule displacements.

MR. KROTIUK: Basically that's the effect that you look at.

MEMBER SIEBER: So if you -- factor of 100 percent --

MR. KROTIUK: This is the duration right here. It's dynamic load factor type thing.

MEMBER SIEBER: Yes.

MEMBER RANSOM: Well, another factor what were the initial conditions? Was this boiling so it was two phase to begin with or was it actually maybe even subcooled water to start out with? That would make a lot of difference to the --

MR. KROTIUK: I don't remember that specifically.

MEMBER RANSOM: Yes. But that would make -- the real case, of course, boiling is taking place and so it's a spongy sort of mixture of a two phase system at a tenuated --

MEMBER SIEBER: Yes, it's even milder.

MEMBER RANSOM: Pardon?

MEMBER SIEBER: The transient's even milder if you have boiling.

MEMBER RANSOM: Sure.

CO-CHAIRMAN FORD: Is there physically a reason why that is not pulse if it's real, is confined to the top U bend region? That it's likely to be less cracks?

MR. KROTIUK: Well, what's --

CO-CHAIRMAN FORD: I don't know. Answer my question.

MR. KROTIUK: What you'll see is that because the break is occurring -- because the break is occurring up here --

CO-CHAIRMAN FORD: Yes.

MR. KROTIUK: -- and the tubes are here --

CO-CHAIRMAN FORD: Right.

MR. KROTIUK: -- the highest forces are in the top and then they decrease as you go down.

CO-CHAIRMAN FORD: Okay. So that's --

MR. KROTIUK: That's just for examples

of.

CO-CHAIRMAN FORD: --in the first two or three tube support plates in the hot leg, we're likely to have cracks. The ⌂p is smaller than anywhere else.

MR. KROTIUK: Yes, the ones on the bottom right here. In fact, when I was doing the calculations I actually saw that possibly on the lowest two support plate you could actually get a downward force instead of an upward force because --

CO-CHAIRMAN FORD: Okay.

MR. KROTIUK: -- the travel of the acoustic waves down the feedwater side, you know. So you do get some balancing that way.

CO-CHAIRMAN WALLIS: So we have here a sort of a verification of the later part of the transient where you get two phase effects and full swell and stuff.

MR. KROTIUK: Yes.

CO-CHAIRMAN WALLIS: But we don't really have a good verification of the initial spike because it wasn't recorded?

MR. KROTIUK: For this test, yes. And that's one of the reason why I was looking at the LOFT, because I'm trying to follow the acoustic waves in that, in that test and compare it to --

CO-CHAIRMAN WALLIS: Well, actually, even if the spike had been much bigger in altitude, it doesn't last very long.

MR. KROTIUK: Yes.

MEMBER RANSOM: Well, the inertia --

CO-CHAIRMAN WALLIS: When you have a pressure if 100 psi for a millisecond, it's not going to move very much.

MEMBER RANSOM: What was that first mark? Were those pressure ratios or were they actual pressures?

MR. KROTIUK: This one?

MEMBER RANSOM: That first -- yes.

MEMBER SIEBER: Actual PSID.

MR. KROTIUK: This is PSIDs.

DR. KUPPERMAN: Differentials.

MR. KROTIUK: Differentials.

MEMBER RANSOM: Oh, differential pressure?

MR. KROTIUK: Yes.

MEMBER RANSOM: ⌂p.

MEMBER SIEBER: Across each --

CO-CHAIRMAN WALLIS: So, in fact, it's not a very good prediction of the green curve with the data and the top curve, that sort of valid phase and it's going up when the other one's going down and so on. But it shows that you don't get large amplitudes.

MEMBER SIEBER: Right. However, one of the bigger questions is if you have tubes that are lofting to the tube support plate, you start getting these spikes, what does it do to the tube?

MR. KROTIUK: That's the next part.

DR. MUSCARA: That's the next part. You'll get there.

MEMBER SIEBER: I can hardly wait.

MR. KROTIUK: Okay. For the specific study, what I did is that I modeled the Westinghouse model 51 steam generator because I had a report that was done by Westinghouse using the -- and RELAP5 codes for doing similar type of calculations, and I wanted to make comparisons with that.

CO-CHAIRMAN WALLIS: So you had an input deck?

MR. KROTIUK: No, not input deck.

CO-CHAIRMAN WALLIS: You didn't?

MR. KROTIUK: I did not have an input deck. I just had description of the model.

And I looked --

MEMBER SIEBER: Is that the one called sensitive study? You have one that we don't have?

MR. KROTIUK: You should have.

MEMBER SIEBER: I have your report.

MR. KROTIUK: It's in my report.

MEMBER SIEBER: Okay. I have the Westinghouse results in my report, but it references the Westinghouse report.

Looked at hot standby and 100 percent power conditions and 100 power conditions and looked at two steamline break and one feedwater break.

Okay. The model that I developed looked like this. And as I said, I did develop the model. And it included basically different volumes, and it included two support plates, it included areas at the top of the steam generator, and also the feedwater area coming -- around and through the center. And it did include a primary system for heat transfer going through the tubes to the central area in the steam generator, from the primary to the secondary side.

CO-CHAIRMAN WALLIS: So, tell me more about what's in the steam generator. There's a boiling mixture --

MR. KROTIUK: There's a boiling mixture.

CO-CHAIRMAN WALLIS: And then there's a steam region at the top. So the wave comes in through steam?

MR. KROTIUK: The wave comes in through steam.

CO-CHAIRMAN WALLIS: So it's all single phase not to be reasonably easy to predict?

MR. KROTIUK: In that part, yes.

CO-CHAIRMAN WALLIS: At the top? Right.

MEMBER RANSOM: Well, there are two paths. The downcomer path.

MR. KROTIUK: Yes.

MEMBER RANSOM: Which presumably would -- the wave reached the bottom first through that one since that one is full of subcooled water.

MR. KROTIUK: Down this way, right.

MEMBER RANSOM: Right. Because it's open to the steamline also.

MR. KROTIUK: This way because there is a depressurization tube down the center.

MEMBER RANSOM: Right.

MR. KROTIUK: And what you do is that it has to be a balance between the two depressurization waves.

MEMBER RANSOM: Right.

CO-CHAIRMAN WALLIS: It actually goes first fastest through the metal.

MEMBER RANSOM: Well, it goes through the metal, too, yes.

MEMBER SIEBER: Well, you're going to get a circulation in there during blowdown.

MR. KROTIUK: I think in the long term we would get a circulation. But I think in the time frame that I looked at the forces were occurring in such a short time frame that --

MEMBER SIEBER: It's subcooled on the outside.

MR. KROTIUK: This was the equation that I used to calculate the force of the tube support plate itself. And it was ⌂p. And it included the frictional loss which was a function of the irreversible loss coefficient plus I included gravity heads and acceleration terms.

It turned out that the gravity head, acceleration terms were really minor compared to the frictional loss but I wanted to include it for completeness.

CO-CHAIRMAN WALLIS: Well, acceleration is small?

MR. KROTIUK: Yes.

CO-CHAIRMAN WALLIS: Oh, that's on the loading. But in the wave transmission acceleration is the whole thing, isn't it?

MR. KROTIUK: Yes, but this is for the loading on the two support plate.

CO-CHAIRMAN WALLIS: So you're not presenting your equation of motion of the fluid?

MR. KROTIUK: No, this is the force on the tube support plate.

CO-CHAIRMAN WALLIS: Again, there is something similar for the actual fluid going through the holes.

MR. KROTIUK: Right.

CO-CHAIRMAN WALLIS: Which isn't the subject of some uncertainties.

MR. KROTIUK: Right.

MEMBER RANSOM: Well, actually those last two terms are the acceleration of the fluid in the hole, right?

MR. KROTIUK: They the acceleration of the fluid in the hole --

MEMBER RANSOM: Right. Kind of finite difference approximation to that, yes.

MR. KROTIUK: It's just within the ⌂T using the ⌂T that was in the code. But it's small compared to -- the main term was the frictional loss coefficient.

MEMBER RANSOM: K, the irreversible loss? Yes.

CO-CHAIRMAN WALLIS: So the main difference -- the main pressure drop through the hole is just simply the flow, the steady state flow loss because you're squirting fluid through the hole?

MR. KROTIUK: That's right.

CO-CHAIRMAN WALLIS: That's interesting, because with just sort of water hammer calculations you usually throw away the friction and you say well let's do inertia by itself.

MR. KROTIUK: Yes, but --

CO-CHAIRMAN WALLIS: That's everything, that's the whole story. Then you put in some friction and see if it makes a difference?

MR. KROTIUK: You're absolutely right. Because if you have pipe that forces the acceleration term,if you have a straight length of pipe between two bends, the maximum force is the acceleration term. Right.

MEMBER RANSOM: Actually, this under dynamic conditions you have to be careful. Because, I mean, really the velocity through the holes is being driven by the ⌂p. And the ⌂p is governed by the depressurization wave that's going through the thing. So in reality the ⌂p's could be much larger than that, but only for an instant. You know, as the acoustic wave passes through the plates.

MR. KROTIUK: Okay. This is a comparison of the forces on the tube support plates. Tube support 7 is on top, which is plate 1 is on the bottom. And it is the forces calculated by TRACE, the RELAP5 model and model which were done by Westinghouse.

CO-CHAIRMAN WALLIS: Now are these the forces in that little spike we talked about earlier?

MR. KROTIUK: Yes. These are the forces in the little spike.

CO-CHAIRMAN WALLIS: So there's no data to compare with any of this? There's no data for transient forces on perforated plates to compare with this?

MR. KROTIUK: Not that I --

CO-CHAIRMAN WALLIS: That's a real hole in the data. There's no data for that initial type spike for --

MR. KROTIUK: But, again, that's why I

was looking at the acoustic phenomena with the --

CO-CHAIRMAN WALLIS: And then I understand later on you had a hand calculation of which it was all acoustics?

MR. KROTIUK: Yes.

CO-CHAIRMAN WALLIS: Then you were throwing out the form loss, which seemed to be the rest of the --

MR. KROTIUK: Well, let's get to that.

This is just the comparisons of the forces calculated for the different conditions the 100 percent power and the hot standby conditions for the different break sizes, the steamline break and the feedwater line break. And what it does show is that the large main steamline break, the 4.6 foot squared break does give the highest loadings on the top tube support plate.

CO-CHAIRMAN WALLIS: How long do these last for, these loading?

MR. KROTIUK: That's the next figure. I'll just show you.

CO-CHAIRMAN WALLIS: Oh, they last quite a long time?

MR. KROTIUK: Just one second.

CO-CHAIRMAN WALLIS: So they can't be

acoustic. That's it's the friction. They establish a flow through.

MR. KROTIUK: Well, it's a combination.

CO-CHAIRMAN WALLIS: Once the wave goes through, you establish a flow. It then becomes essentially steady flow.

MR. KROTIUK: Yes. But it's close enough that they both have a component in there.

CO-CHAIRMAN WALLIS: Yes.

MR. KROTIUK: And then I did do a conservative bounding calculation. And then is, like you were saying, it's completely following an acoustic wave starting at the pipe rate, traveling through the central part of the steam generator and also going on the outside of the feedwater annular area. And basically I used just the Moody methodology just to come up with the initial value for the depressurization wave. Follow that through geometry. I looked at the drawings. I got drawings and looked at the geometry changes and tried to figure out how much would be transmitted and how much would be reflected.

And then followed it to the first top two support plate. And then had a reflection and a transmission through that tube support plate and then down to the second one, lowest one, and so on.

CO-CHAIRMAN WALLIS: And the huge attenuation is going for the steamline to the vessel. And it's a huge area ratios; that's what does the tremendous attenuation from --

MR. KROTIUK: Right. Yes. Right.

But the next largest attenuation, actually, was at the tube support plates themselves because of such a small area across the --

CO-CHAIRMAN WALLIS: You said 84 percent of the weight went through. That's because there's a big hole in the plate.

MR. KROTIUK: Yes.

CO-CHAIRMAN WALLIS: I was surprised so much wave went through.

MR. KROTIUK: Yes, but that's just a function of areas.

CO-CHAIRMAN WALLIS: Yes, but there's a lot of open area there. That's why it goes through.

So what sort of numbers for pressures are they worried about that would effect these plates? Is there a problem that extend psi or a five or a 100?

MR. KROTIUK: He's present that, go through that.

CO-CHAIRMAN WALLIS: He's going to present that.

MR. KROTIUK: Basically the valleys that were calculated using a hand calculation were of the same order of magnitude that were calculated by TRACE. I can't differentiate in a hand calculation between 100 percent power in the hot standby case, but these results are probably closer to the hot standby case.

CO-CHAIRMAN FORD: When you say bounding calculations?

MR. KROTIUK: That's my hand calculation, that's why I'm calling it a bounding calculation.

CO-CHAIRMAN FORD: It doesn't mean worse case calculations? Bounding to me means this is the worst it could possibly be. I was about to ask you the question well what physically is making it the worst possible?

MR. KROTIUK: Yes. I guess maybe in my -- and my terminology may have been wrong. It's the best calculation that I could do using --

CO-CHAIRMAN WALLIS: It's probably worst, because RELAP predicts something bigger.

CO-CHAIRMAN FORD: Is it just a modeling

artifact that RELAP is bigger than the others or -- can you give me a feeling for physically? How much error could we have here? Could it be 18? Could it be 20 psi?

MR. KROTIUK: I think this is the order of magnitude. You know, probably 10 psi, 12 psi, something of that nature.

CO-CHAIRMAN FORD: So it's unkind to say it, but suppose the designer of the Challenger said "I thought that this is the worst case scenario," but he was wrong.

MR. KROTIUK: I've been there. I've worked for the aerospace industry, too. So I've been there.

CO-CHAIRMAN FORD: Well, that's great. I mean, there's a feeling when you say you think it that it couldn't possibly be 20 PSI. You have a factor of 4 between two lots of --

MR. KROTIUK: I think the hand calculation or what I called the bounding calculation, if you want, at least gave us a good order of magnitude. So we know the order of magnitude of -- whether it's -- I can't envision that calculation coming up with something that would be more than a factor of two different, you know, than reality. So I think the most that I would really think would really be something like, you know--

CO-CHAIRMAN WALLIS: It is kind of bounding. I mean, it is reversible, it assumes no losses and stuff. So I think it would be applicable.

CO-CHAIRMAN FORD: Okay. So it's a physical reason --

MR. KROTIUK: But I mean, there could be some problems with the two. I wouldn't -- I just wouldn't say that it's more than like 18 psi, you know.

CO-CHAIRMAN WALLIS: I think it's interesting. His tran flow is a lot smaller. Is that a Westinghouse code?

MR. KROTIUK: That's a Westinghouse code.

CO-CHAIRMAN WALLIS: Is that an approved code for use?

MR. KROTIUK: That was the code that they originally used for the calculation and --

CO-CHAIRMAN WALLIS: Did the NRC approve it?

MR. KROTIUK: No.

CO-CHAIRMAN WALLIS: Because you might be in trouble at NRC to prove tran flow and it was in the regulations that it was okay to use it, and here it --

MR. KROTIUK: The documentation that I read basically, and this was a number of years ago, the NRC asked them to redo the calculation with RELAP5.

MEMBER RANSOM: Incidentally, when you give the Moody calculation, did you use the speed of sound --

MR. KROTIUK: Excuse me. Let just go to my notes here.

CO-CHAIRMAN WALLIS: Did you homogenous--

MR. KROTIUK: Okay. I used the speed of sound in steam and the water that was appropriate for where it was, but I also modified the speed of sound to take into account, not giving the homogeneous value, but I have curves that gives a -- I did work a number of years ago that shows that the speed of sound in a two phase mixture, it actually for high void fracture, is actually very, very close to the steam.

MEMBER RANSOM: Right.

MR. KROTIUK: Yes.

MEMBER RANSOM: You probably used the frozen speed of sound rather than equilibrium sound?

MR. KROTIUK: Actually, it wasn't even the frozen, what I would say the frozen. Because I had done this many years ago, they had big curves comparing it with test data. That actually had some test measurements.

CO-CHAIRMAN WALLIS: Because the homogeneous is low.

MR. KROTIUK: Yes, the homogeneous is low.

CO-CHAIRMAN WALLIS: Way low.

MR. KROTIUK: That's why I didn't use the homogeneous. I was basically using -- it was my experience just from test data that I had in coming up with these correlations. It's more of a fit saying, gee, if I'm in the void fraction from -- I don't know -- points -- I don't remember. But say .5 on up, I used the steam speed of sound.

MEMBER RANSOM: That's almost like the stratified speed of sound then, it's high slip between the phases. But I don't think it makes a lot of difference probably.

You're talking about speeds from a

thousand down to a 100, and the homogeneous is down around ten to one.

MR. KROTIUK: Yes, but homogeneous I wouldn't believe. I mean, you know the homogeneous speed of sound is --

MEMBER RANSOM: No, I'm not suggesting that you should.

CO-CHAIRMAN WALLIS: It's possible to get it. If you really disperse the phases, you can get it.

MR. KROTIUK: The test data that I had didn't show that.

MEMBER RANSOM: I think if we don't hear on, we won't get a chance to hear about the results.

MR. KROTIUK: Okay.

CO-CHAIRMAN WALLIS: And now we're going to hear about the mechanics.

MR. KROTIUK: Okay. I was finished.

Basically my conclusion is that the code is able to give me some results that were --

CO-CHAIRMAN WALLIS: Are you going to load these spaces and one tube is attached to them, even a breaker tube and -- you're not worried about the deflection of the spacer by itself, particularly?

CO-CHAIRMAN FORD: Now, Joe, just for calibration here, what we've heard is the calculated loads on tube support plates. That was item 3.1a. Are we going to hear now about the flow assisted vibration, or was that somehow covered in that 3.1a?

DR. MUSCARA: The vibration loads were also predicted by the thermal hydraulics work.

CO-CHAIRMAN FORD: Yes. Okay. I noticed it was somewhere. Okay.

DR. MUSCARA: And then showing us the technique to look at those loads and seeing --

CO-CHAIRMAN FORD: And there is no need for any additional sensitivity studies?

DR. MUSCARA: I think the loads --

CO-CHAIRMAN FORD: Fine.

DR. MUSCARA: -- I think that's correct.

MR. MAJUMDAR: Thank you.

My name is Saurin Majumdar. I am from Argonne National Laboratory, Energy Technology Division.

What I did was I took Bill Krotiuk's ⌂p data and applied them to the tube support plates in a model 51 SG steam generator and see what happens.

CO-CHAIRMAN WALLIS: You have 38 slides?

MR. MAJUMDAR: Yes.

CO-CHAIRMAN WALLIS: That's 2½ minutes per slide.

MR. MAJUMDAR: I'm going to go fast. Because, again, the question I'm trying to answer is does the TSP movement, the pressure across TSP causes the TSP to deflect. And in model 51 steam generator the tubes are rarely locked to the TSP and so they move. And the question is can the cracks grow, grow unstable, what are the margins? Do we need any other defined TH analysis?

Before we did any analysis, we went and did a literature survey, and this is the (unintelligible due to strong foreign accent [UDTSFA]) report what Bill was referring to. And they did a RELAP5 calculation for pressure distribution. They also did an final element analysis for the dynamic -- actually dynamic elastic environment analysis of the whole steam generator tube system. But their objective was different from ours. What they wanted to show was that TSPs move would not be enough to expose the cracks that easily lie within the TSPs. And so that was their objective. And they were basically able to show that if all the tubes they're locked to the TSPs, the cracks would not be exposed.

CO-CHAIRMAN WALLIS: I'm puzzled by this. Because when they manufacture the steam generator, the tubes have to slide through the support plates. So when it's new and clean, they're not locked.

DR. MUSCARA: No, no.

CO-CHAIRMAN WALLIS: So it take some time for them to be locked. I didn't see in any of this discussion how long it takes to lock the tubes. If it takes five years to lock a tube, then you're not really justified in assuming any of them are locked. But if it takes five minutes to lock a tube, then that's good.

DR. MUSCARA: That will be conservative.

CO-CHAIRMAN WALLIS: Isn't that very important, though?

DR. MUSCARA: Yes. Yes. And it'll come out in the presentation.

CO-CHAIRMAN WALLIS: And he will talk about the time to lock?

MR. MAJUMDAR: No.

DR. MUSCARA: But in general if you're looking at replacement generators, even with the new chemistry and the materials, very often within one fuel cycle the crevices start to get filled up. And so they start to provide some restriction on the tubes.

Now, in the old generators when the tubes are also denting, it'll give you even much more locking force. But it's been noticed that even within one refueling outage, they're beginning to lock.

CO-CHAIRMAN WALLIS: So the locking happens quicker than the crack growth, is that right?

DR. MUSCARA: Well, in fact, you exactly need the conditions that produce the locking, that in turn produces an aggressive chemistry and then the cracking begins after that.

MR. MAJUMDAR: Yes, but locking problems appears in different way from the model E2, it was another (UDTSFA) report. In this case they're using ferritic stainless steel TSPs and they're not locked. What they wanted to do was they wanted to also show that TSP displacement during an MSLP could be kept from controlled --

CO-CHAIRMAN WALLIS: If they're not locked, they don't load the tubes at all, do you? They just slide on in?

MR. MAJUMDAR: That's right. But in

this case--

CO-CHAIRMAN WALLIS: If they're locked to one --

MR. MAJUMDAR: In this case they purposely take hydraulically expanded 16 tubes. So they analytically showed that if you hydraulically expand 16 tubes at 3 TSPs, that will be sufficient to minimize the maximum TSP disbursement relative to the tube so the cracks out of the tubes several places don't get exposed.

CO-CHAIRMAN WALLIS: Do they do that?

MR. MAJUMDAR: I don't know. I -- they asked for this proposal was there. I'm not sure whether the NRC approved it or not. Was it approved?

DR. MUSCARA: I know it was reviewed. I know there were some initial questions, but I think it eventually was approved.

MR. KARWOSKI: The staff has approved several amendments where the licensees locked the tube support plates by hydraulically expanding. That's been done at a number of plants. Currently I don't believe any of them are in operation, plants have replaced. But that has been done. Whether or not 16 tubes at three tube support plates is the right number, I can't say. But the proposal to lock the support plates and limit the tube support plate motion, that has been approved.

MR. MAJUMDAR: What is interesting, is that you don't need many, many tubes. All you need is 16. Out of more than 3,000 tubes, only 16 tubes are sufficient to minimize the displacement.

CO-CHAIRMAN WALLIS: Well, that makes sense. The loads are very low pressure difference.

MR. MAJUMDAR: So basically the conclusion from the industry analysis as it is relevant to us is that the affected bending stiffness of the TSPs is much less than the axial thickness of the steam generator tubes so the steam generator tube can really push them up and down. That's because the TSPs are full of holes, as you mentioned earlier.

CO-CHAIRMAN WALLIS: Right.

MR. MAJUMDAR: Now I did some additional abstract imagery and supplementary final analysis --

CO-CHAIRMAN WALLIS: How thick as these TSPs?

MR. MAJUMDAR: They were 3/4-inch.

CO-CHAIRMAN WALLIS: And the holes are?

MR. MAJUMDAR: 7/8-inch or a little bit

more.

CO-CHAIRMAN WALLIS: The holes are comparable with the thickness?

DR. MUSCARA: Yes. A little bit of degradation. Yes.

MR. MAJUMDAR: It's like a swiss cheese, it varies.

CO-CHAIRMAN WALLIS: So a free support plate under the load would --

MR. MAJUMDAR: Would really deflect a lot.

CO-CHAIRMAN WALLIS: But it would also essentially bend --

MR. MAJUMDAR: Yes.

CO-CHAIRMAN WALLIS: -- and tend to grab the tube by bending around?

MR. MAJUMDAR: That's right. There are all kind of other influences.

CO-CHAIRMAN WALLIS: That doesn't seem to be considered.

MR. MAJUMDAR: As you can see, the most critical problem is that one tube gets locked and all the other tubes are free to slide. That would be the worst from the tube integrity point of view.

The smaller number of assumption in the

model 51 case that all tube intersections are dented or packed is limiting case. That's the most benign. That's what they're assuming there were (UDTSFA) in the first report, where all the TSP junctions are locked. But the question is what happened in one and all the tubes locked, that what this I looked at. I'm looking at 1, 2, 4 and 10 tubes locked in a local area.

CO-CHAIRMAN WALLIS: This support plate is held on the outside parameter?

MR. MAJUMDAR: Yes. I showed the support in the drawing I have.

CO-CHAIRMAN WALLIS: So it's not attached to a tube at all. Does it break free at the outside?

MR. MAJUMDAR: No, it doesn't. It's welded to the wrapper.

CO-CHAIRMAN WALLIS: It's welded all around?

MR. MAJUMDAR: Yes. Not all around, but the wedges and blocks and they're welded to the wrapper.

First I looked at this dynamic pressure loading on the (UDTSFA) tubes. Then I looked at the triangles, dynamic pressure and of course TSPs that we had just talked about. And I got the number from Bill.

This is for the transverse dynamic pressure loading on the steam generator tube. These analyses show that there is a transverse load, dynamic load on the lower third of the tube support, the first tube support tube in the tube sheet and the tube support plate. So this part is significant, especially with a history like that.

This is the feedwater line break, and it is a very large break from MSLB. So again, in MSLB gives a much higher pressure -- a higher pressure than the feedwater line break.

CO-CHAIRMAN WALLIS: So they're pushed sideways?

MR. MAJUMDAR: Yes. That's the sideways push on the --

MEMBER RANSOM: How did you estimate that?

MR. MAJUMDAR: That came from Bill's calculation.

MEMBER RANSOM: Whose?

MR. KROTIUK: When I did the calculations, I didn't show that. On one of the viewgraphs I said that I calculated differential pressures across the tube support plates, across the cylindrical area between the central area where the tubes are and the feedwater area, and also across the bend on the tubes on the top of the -- towards the top of the steam generator. So, that's --

MEMBER RANSOM: The velocity is automatically zero.

MR. KROTIUK: What do you mean?

MEMBER RANSOM: You're talking about flow across the tubes, right, in a horizontal direction?

MR. KROTIUK: No. We're talking about vertical flow.

CO-CHAIRMAN WALLIS: That's not what it looks like here. How did you get a sideways force?

MEMBER RANSOM: But the pull, you're talking about the lateral --

MR. KROTIUK: Oh, yes. Because it's just what you alluded to previously, is the fact that the acoustic wave is traveling at different rates down the center and at different rates down the feedline. So that causes a differential pressure across that cylindrical area.

MEMBER RANSOM: Since you don't know what the distribution is, what do you assume?

There's some water on one side --

MR. KROTIUK: I didn't make an assumption. The initial conditions in the feedwater area, that was liquid initially. And in the central area it was varying; as you went up you were getting boiling. So there were varying void fractions as you're going up. But --

MEMBER RANSOM: You did this by hand?

MR. KROTIUK: No, did not do this. This came out of TRACE.

MEMBER RANSOM: But you didn't put a multidimensional model in the curves. You only put a one dimensional model.

MR. KROTIUK: That's correct. So this is just either a pressure out or a pressure in on the cylinder.

MEMBER RANSOM: I don't understand it at all. I mean, you only have one pressure and one velocity in a one dimensional model, so I'm curious how would you estimate the transverse force then?

MR. KROTIUK: It's like a pressure force, that's all it is. It's like --

MEMBER RANSOM: Well, pressure has to have delta?

MR. KROTIUK: Right, there's a ⌂p.

MEMBER RANSOM: So what are the two pressures? There's only one calculated.

MR. KROTIUK: Okay. ⌂p is across the cylindrical area --

MEMBER RANSOM: Oh, the shroud, you mean?

MR. KROTIUK: The shroud.

MEMBER RANSOM: Oh, shroud. I thought you were talking about the pressure across the tubes.

MR. KROTIUK: No, no, no. The shroud. I'm talking about the shroud.

MR. MAJUMDAR: I misunderstood. I thought I had it -- I thought it was the bottom third of the tube was subjected to this pressure, but never shroud.

MR. KROTIUK: That's the shroud, yes.

MR. MAJUMDAR: Not the tube?

MEMBER RANSOM: So it's not the tube?

CO-CHAIRMAN WALLIS: So you've been loading them upside down.

MR. KROTIUK: All right.

CO-CHAIRMAN WALLIS: I was wondering how you managed to load the tubes.

MR. KROTIUK: Okay. Anyway, what we did

was --

CO-CHAIRMAN WALLIS: You loaded the tubes anyway, and they bend sideways?

MR. MAJUMDAR: Yes, they bend sideways. But I guess we're not -- what I wanted to show, I said do we need to come back to dynamic analysis for this kind of a tube geometry. So I did several dynamic, elastic dynamic analyses, one with .01 second rise time pressure pulse, .02 and here it is one second and then there was a study.

As you can see, as for the one second rise time it's almost (UDTSFA) study, actually rides on top of each other. And you've got to consider the dynamic effects. If the rise time gets much shorter than .01, or a total of .01. But you will see, most of the rise times are (UDTSFA) half second or quarter second once again. So we concluded that the static analysis should be okay for a rise time for .1 second.

If you look at Bill's pressure (UDTSFA), the rise times are much better than .01 seconds. So this is telling the static analysis is all right.

Okay. This is the bounding conditioning he's talking about. This is a typical tube support plate here and they got fixed supports here, there.

These supports on the edge are rendered to the wrapper. And the tierods, they circle the tierods. They go from the bottom tube sheet to the top two support plates. And all these tierods and wedges in this thing are much more rigid than tube. So what we assume, that this provided specifically rigid support to the tube support plate. And there's one tierod right of the center of a tube support plate.

MEMBER RANSOM: Are those rods welded to the plate or are they --

MR. MAJUMDAR: The rods go through the plates. They are fed into the tube sheet at the bottom and welded at the top.

I think the first tube support plate might be welded to the rod, but not all the second-- they're not welded. They got spaces in between each support plate.

MEMBER RANSOM: Spacers? Yes.

MR. MAJUMDAR: Now basically what I did was I did a series of unit pressure drop analyses. That means that I have subjected each of the TSP to a unit pressure drop keeping the others unloaded and completed the stresses and displacement. So what each analysis had unit pressure and a single TSP with the rest of the TSPs unloaded. Then I used principle of superposition were used to combine the pressure loading on all the TSPs.

So I had the pressure loading from Bill's calculation. I could apply those pressures to all the TSPs. And based on this unit pressure drop analysis we computed the total stress.

Now if you look at just a single TSP with that ⌂p or one psi without any tube lock, no tube lock; this is the center of the tube and this is the outer wall support. It deflects like this, as you would expect it has deflections. The tube is very difficult but it is flexible and you get .04 of displacement.

If you put a tube here that is locked, that brings down the displacement to this value. The maximum displacement now moves to this area here. So the maximum displacement is reduced .44 to .054 here. That's for the introduction of one tube lock. The rest of the tubes are unlocked. And the maximum von Mises stress in the plate is reduced from 7 to 3 ksi.

CO-CHAIRMAN FORD: I noticed in your code you used three decimal places. This is a calculation?

MR. MAJUMDAR: Yes.

MEMBER RANSOM: I haven't thumbed through here, but will you be showing some observation versus calculation?

MR. MAJUMDAR: We had no test did on this.

CO-CHAIRMAN FORD: Okay. Is this so well known it's just like one plus one equals two?

MR. MAJUMDAR: This is elastic analyses. It is very similar.

CO-CHAIRMAN FORD: There's no reason to question these calculations?

MR. MAJUMDAR: As long as you know the pressure and the boundary conditions, the analyses is pretty straightforward.

CO-CHAIRMAN FORD: Okay.

MR. MAJUMDAR: So basically what I did was I applied a unit pressure loading to all the tube support plates and I am plotting here actual load goes essentially near the tube versus the intervention of all the tube (UDTSFA). But this is 1 psi on the first TSP so the load is specifically taken up as it tensile load below the tube support plate. And there is a slight compressive load taken by the (UDTSFA) the tube below the TSP is subject to the tension on the tube flying above the seven tube support plate there's a little compression. And same thing for all the seven tube support plates.

So once we have this, then we can use the results from all these seven cases and then apply (UDTSFA) to get the final answer.

MEMBER RANSOM: Out of curiosity how do you make this calculation for this plate which is full of holes?

MR. MAJUMDAR: Okay. It's a good question.

I took the flat bending flexibility number from the Westinghouse -- the Westinghouse (UDTSFA) report had the number for the bending stiffness for the tube support plate.

MEMBER RANSOM: And that would include all the holes?

MR. MAJUMDAR: All the holes. That's an involved calculation.

CO-CHAIRMAN FORD: I'm trying to think of the downside to this. For instance, isn't this like a bongo drum? I mean, couldn't you wang it and it deflects a small amount but it could reverberate? It could --

MR. MAJUMDAR: That's what I show in the first couple of slides back, do I need a dynamic analyses or not? But the rise times were slow enough that this static analyses is good enough on these kind of -- and I show frequencies pretty -- very high.

CO-CHAIRMAN FORD: Okay.

MR. MAJUMDAR: So time period is pretty small compared to the time period of the rise time on the pressure pulse.

CO-CHAIRMAN FORD: It's so damped that--

MR. MAJUMDAR: Yes.

CO-CHAIRMAN FORD: Okay.

MR. MAJUMDAR: The dynamics of this are not really playing a part. Well, in fact, Westinghouse also observed the same thing. The end started -- static analyses whether than dynamic analyses.

And the last slide I showed the load. Now here I'm plotting the stress. So I'm plotting the direct axial stress and also the bending stress, these are the dashed lines here. At the TSP, stress -- it introduces bending stresses in the tubes that are locked to it. As you can see, the bending stresses are small compared to the direct actual stresses. So the effect of bending stresses on the rupture of flawed tubes we already know, so we know the effect of the bending stress on the rupture, but we investigated the effect of the bending both analytically and then experimentally by a series of experiments. And the results show that the bending stresses can be ignored when analyzing rupture of the steam generator tubes.

So in all my calculations I did know the bending stresses on the tube rupture.

CO-CHAIRMAN FORD: I'm sorry to keep questioning your veracity. But is there any other equivalent structures? I mean there's lot of heat exchangers out in the business. And have these sort of approaches been used on them and shown to be accurate?

MR. MAJUMDAR: Yes, pretty routinely. They analyze steam generator tubes using this kind of a unrelevant approach. And --

CO-CHAIRMAN FORD: Okay.

MR. MAJUMDAR: -- I can't off the top of my head remember any study that showed the analysis is good. But elastic analyses, it's pretty straightforward. There's not -- it's not elastic, plastic creep or anything like that.

CO-CHAIRMAN FORD: Okay.

MEMBER RANSOM: One question I have on

these tube support plates, I know that some steam generators had -- they were not symmetric. You know, they were made to have cross flow or cross --

MR. MAJUMDAR: Yes, they use heat usually.

MEMBER RANSOM: That's true here?

MR. MAJUMDAR: No, that's not here. The model 51 doesn't have a heater.

MEMBER RANSOM: Does not have that?

MR. MAJUMDAR: No.

MEMBER RANSOM: Some steam generators do have that then?

MR. MAJUMDAR: The E2 model, has a heater and --

MEMBER RANSOM: Which one?

MR. MAJUMDAR: Model E2.

MEMBER RANSOM: I'm wondering if that's -- that one would certainly be different than these steam generators. Is this study only directed toward this?

MR. MAJUMDAR: Model 51.

MEMBER RANSOM: Only 51.

MR. MAJUMDAR: Only with carbon steel TSP which showed this locking of the tubes to the tube support plate.

MEMBER RANSOM: I guess I'm asking the bigger question. This whole question of main steamline break and containment bypass, is it only concerned with systems which have that steam generator?

MR. MAJUMDAR: That's --

MEMBER SIEBER: That's the most severe case?

MR. MAJUMDAR: That's the severe case.

MEMBER SIEBER: Model 51.

DR. MUSCARA: Most of them have one of those generators inservice.

MEMBER SIEBER: Of that period, there's a model 54 now that gets us --

MR. MAJUMDAR: The 44 is very close --

MEMBER SIEBER: 44 has a less stored energy than a 51.

CO-CHAIRMAN FORD: But I think the answer to Vic's question is isn't that true that that's the only design that's got round tube support plate holes with a carbon steel support plate, and therefore it's likely to be the most degraded one?

MEMBER SIEBER: Everything before model 51 or before are all carbon steel drove tube support plates. The E2 and the F -- E2 was stainless. The

F was carbon. And then the plates came after that.

MR. KARWOSKI: This is Ken Karwoski from the NRR staff.

With respect to are there other models besides model 51 steam generators that have stress corrosion cracking at the tube support plates? The model D steam generators have drilled hole tube support plates, have stress corrosion cracking.

There are two plants that currently implement the Generic Letter 95-05 Ultimate Repair Criteria that have the pre-heater design steam generators.

MEMBER SIEBER: Right.

MR. KARWOSKI: And they do implement the criteria. So there are two plants out there that have that type of design.

MEMBER RANSOM: The only reason I asked that is, of course, there are some lateral forces on the tubes in those designs that are not being considered here.

MEMBER SIEBER: Well, it seemed to me Westinghouse did a similar study on the pre-heater type --

MR. MAJUMDAR: Maybe that's the (UDTSFA)

MEMBER SIEBER: Right. Right. So it's

not like that case has been ignored, but this is probably a more severe case?

MR. MAJUMDAR: Now I look at multiple locked tube case just after our one tube lock. In the case of drilled support plate, it is highly unlikely that only a single tube will be locked because these are caused by corrosion, so corrosion is really related to a small, small area. So there should be more than one tube that's really locked at the TSP. So we conducted analyses to where two, four and even 10 tubes are locked, about a quarter of the TSP. So we model only one quarter of the TSP.

MEMBER SIEBER: Right. Wasn't there a case where tubes were intentionally rolled into the --

MR. MAJUMDAR: Yes, that's what I said. In that model E2 intentionally hydraulically expanded the tubes.

CO-CHAIRMAN WALLIS: Because they are getting from being new and not stuck to being totally locked, what sort of stage do they go through?

MR. MAJUMDAR: That's a good question.

CO-CHAIRMAN WALLIS: Are they partly

locked, are they --

MR. MAJUMDAR: Usually they do a tube pull test, and there's some force at which point the tube start slipping from the tube support plates. Tube pullout. I'm talking about the tube pullout load. But I don't know whether they go through a transient of they're not semi-locked, quarter locked. There must be some rate of locking. I don't know. There has been no study -- I don't think so.

DR. MUSCARA: Well, we've measured forces for pulling tubes, for example, out of the McGuire. And we did some work on the Surry generator that we studied at PNL. And in most cases it showed one to two thousand pounds of pull to move the tubes from the support plates.

So when they're locked, they're locked in.

MEMBER SIEBER: They're locked.

DR. MUSCARA: Yes. But your question was what's the transition from being free to being fully packed, and all I can mention is that the observation that even within one fuel cycle the crevices get to be packed.

CO-CHAIRMAN WALLIS: They get locked solid?

MR. MAJUMDAR: Well, it's difficult to say because there's not that much --

CO-CHAIRMAN WALLIS: Because you can still pull them out?

MR. MAJUMDAR: Oh, yes. There's some, pounds of force to pull them out.

MEMBER BONACA: Although if you have many locked together, then even if they're not locked solid, the question is how do you get there? I mean, is there a correlation somewhat to the degraded steam generator where you have many tubes already cracked and they're locking?

DR. MUSCARA: Well, if you're looking at the support plate cracking, those tubes are locked and cracked.

MR. MAJUMDAR: Yes.

DR. MUSCARA: If you're looking at new generator, you know at the beginning it's not cracked and not locked. But that's the best situation. If there's no degradation, there's no force transmitted to the tube. If there is a corrosion problem going on, it doesn't happen just in one tube. It happens widely over an area. And that's a good situation also because then the load is shared by many tubes.

MEMBER BONACA: That's right.

DR. MUSCARA: And the calculations we've done here are quite conservative because we assume that the load is shared only between one and ten tubes, and it's normally hundreds if not thousands of tubes that they are locked and share the load.

MR. MAJUMDAR: As you can see that maximum stress actually down. This is our most effected tube down from when the one tube was locked. And that's putting two instead of one, halves the maximum.

CO-CHAIRMAN WALLIS: I find it strange to assume that one tube out of 3,000 is locked. I would think it's more likely that --

MR. MAJUMDAR: Yes, that's true.

CO-CHAIRMAN WALLIS: -- 3,000 are in different stages of getting partly locked.

DR. MUSCARA: That's right, and that's the point we are making. So this is a very conservative assumption.

CO-CHAIRMAN WALLIS: Well, I don't know whether it is or not, because I don't really know how it gets to be locked. You're telling me it sounds as if it's conservative. I don't know until there's some sort of evidence that says when they get locked --

MR. MAJUMDAR: But from the tubes -- from the -- if the tube support plate is not locked to the tubes, then the tubes are safe. There is no problem with the tube. No load is transferred to the tube. It's only when they get --

CO-CHAIRMAN WALLIS: So when they're unlocked there's no problem and when they're locked there's no problem. But there's a certain period of time, a window when it could be --

MEMBER SIEBER: Well, there is an instant in time when one tube is locked.

CO-CHAIRMAN WALLIS: And others?

MEMBER SIEBER: But you start from zero and go to some other number. So there's got to be the first one.

DR. MUSCARA: But it's not just one tube that gets lock. There is a generic problem that's going on in the generator, and it's the corrosion. And so you have different degrees of locking even at the beginning.

MEMBER SIEBER: That's right.

DR. MUSCARA: Because it effects many tubes at the same time.

MEMBER SIEBER: You get drag.

DR. MUSCARA: So maybe one may get sooner to be completely locked, but they all experience some degree of locking.

CO-CHAIRMAN WALLIS: So the real thing to do would be to show that after one month that the average lock is worth 200 pounds of pull or something. Then you've got something to work with. Otherwise, it's sort of someone's guess.

MEMBER SIEBER: It's too late. It's too late, though.

CO-CHAIRMAN WALLIS: It's too late? You don't know that.

MEMBER SIEBER: The only way you can do that is by analysis. It's too late because it was 25 years ago.

CO-CHAIRMAN WALLIS: So you're only worried about old steam generators?

MEMBER SIEBER: Yes.

DR. MUSCARA: Well, again, even with new generators if we're going to experience a degradation mechanism it's going to affect a number of tubes. So there's never a situation where we only have one tube completely locked. If there's a tube locked, I would be willing to bet there are many more there are locked.

MEMBER SIEBER: Yes. But the new generators have the quatrefoil design or egg crate, or something like that which are less likely to lock.

DR. MUSCARA: Yes. But this is the example I was bringing out earlier. If you look even at the replacement generators with the guartrefoil design and stainless steel support plate, the crevice gets filled up sometimes or often within the first cycle.

MEMBER SIEBER: Yes, that's true.

DR. MUSCARA: Now there's no denting necessarily but it's filled up.

CO-CHAIRMAN WALLIS: It gets filled up with corrosion which is happening on the steam generator tubes or with the crude that comes from somewhere else?

DR. MUSCARA: No, no. It's crude --

MEMBER SIEBER: Crude.

DR. MUSCARA: -- in concentration within the crevice.

CO-CHAIRMAN WALLIS: That comes from somewhere else?

DR. MUSCARA: Sure. Transport, yes.

CO-CHAIRMAN WALLIS: And it settles or

is jammed into the space somehow and then attaches itself and grows a little bit?

DR. MUSCARA: It doesn't necessarily grow unless we're talking about carbon steel support plate, which the carbon steel gets attacked and the volume of the magnetite is twice the volume of the ferritic material. But if the crevice gets filled up, then there's also a chance for chemicals to concentrate, which in turn will provide an aggressive water temperature and corrosion of the tube.

CO-CHAIRMAN WALLIS: I just don't know how a sort of deposit which is coming out of the water. I can understand it sort of getting in the crevice. I can't quite understand how it locks.

MEMBER SIEBER: Well, it builds up because it's boiling.

CO-CHAIRMAN WALLIS: It has to bound with something. It doesn't just get deposited. If you deposit dust --

DR. MUSCARA: The volume of the oxide is greater than the mechanism.

CO-CHAIRMAN WALLIS: So it's coming in from -- it's just dropped out of the water that's circulating?

CO-CHAIRMAN FORD: No. It's coming from the corrosion of the carbon steel.

CO-CHAIRMAN WALLIS: No, that's not what he said.

MR. MAJUMDAR: No, the corrosion product. The corrosion product versus --

DR. MUSCARA: They are both problems. If you have the carbon steel support plate, it corrodes--

CO-CHAIRMAN WALLIS: Yes, that's it, but the other ones don't.

DR. MUSCARA: -- resupplies the volume and it locks and dents the tube. In a generator that has stainless steel plate --

CO-CHAIRMAN WALLIS: Right.

DR. MUSCARA: Those crevices also get filled up --

CO-CHAIRMAN WALLIS: But it's not the same mechanism, so I don't understand how those lock. I can understand depositing stuff in there, but unless there's some demonstrate --

DR. MUSCARA: Well, because the crevice gets filled with a very tenacious semitacious material.

CO-CHAIRMAN WALLIS: In other words, it

sticks in some way?

DR. MUSCARA: Oh, definitely. I mean, sometimes you can't even -- you know, you have to hammer the thing apart.

CO-CHAIRMAN WALLIS: But just a deposit coming out of solution. I think it's the dust in a room and falling into a hole, it doesn't just jam the hole.

DR. MUSCARA: It's metallic, it's magnetite, you know, corrosion products --

CO-CHAIRMAN WALLIS: And it bounds in some way.

MEMBER SIEBER: And corrosion actually takes place in the crevice of these --

CO-CHAIRMAN WALLIS: In that case, it would ball, I can see that. I can see that. Unless there's chemistry in the crevice which is --

DR. MUSCARA: That's right. The corrosion product plus as the chemistry get worse and worse and then there's corrosion --

MEMBER SIEBER: Concentrates, because there's boiling.

MR. MAJUMDAR: So basically all the purpose of this slide is to show there as I -- there are locked more and more tubes at maximum stress and drops down almost in direct proportion to the number of tubes locked.

Now, next I take all this unit pressure drop analyses and apply it to the large MSLB from hot standby, which was --

CO-CHAIRMAN WALLIS: But it all goes away because you've got so many tubes that are likely to be locked?

DR. MUSCARA: Yes, that's right.

CO-CHAIRMAN WALLIS: So it isn't a problem, is it?

DR. MUSCARA: That's what we conclude.

MEMBER RANSOM: You're better off.

DR. MUSCARA: And I guess we're finished.

CO-CHAIRMAN WALLIS: But it's a qualitative sort of thing.

MR. MAJUMDAR: So we took those out, any pressure drop analysis.

And the one thing I forgot to mention is that we take Bill Krotiuk's pressure drop numbers and then actually multiple them by 1.5, as I say, a safety factor or uncertainty factor. This is the number he recommended that we use.

MEMBER RANSOM: Could you remind me of

what K-I-P-S means.

MR. MAJUMDAR: Okay. Thousand pounds is one kips. One thousand pounds --

MEMBER RANSOM: Pounds?

MR. MAJUMDAR: Yes.

DR. MUSCARA: It's like psi times a thousands.

MR. MAJUMDAR: Not psi, pounds. Load force.

MEMBER RANSOM: Right.

MR. MAJUMDAR: An actual force.

CO-CHAIRMAN WALLIS: Pounds at the end of the kips.

MEMBER RANSOM: Kilopounds, right?

MR. MAJUMDAR: Ah, a kilopound.

MEMBER SIEBER: Very good.

MEMBER RANSOM: I know I've encountered it before, but I couldn't remember.

MR. MAJUMDAR: Okay. Now, we assume --

CO-CHAIRMAN WALLIS: So a pound force is the weight of a pound on earth?

MEMBER SIEBER: That's right.

MR. MAJUMDAR: You see a pound in this, and in England --

First of all, I assumed the case where

there's no slippage between the TSP and the steam generator tube, a complete locking. And I show the total axial load of the TSP to the function of the TSP number here. As you can see, for when one tube is locked you got very high loads of psi -- kips actually. And it actually takes five kips to even make the tube yield. So these tubes here would probably yield and probably rupture, might even rupture.

On the right side I show the pullout load at the TSP. At each TSP the pressure load on the TSP gets transferred to the tube. There is a pullout load at each TSP and tube junction. And as you can see on the seven tube support plate they have the highest tube pullout load, because remember the pressure drop on the number seven TSP are the highest of all the seven tube support plate.

And at the bottom of the steam generator, the load is negative because the pressure reverses at the bottom first tube support plate.

Now, the total axial load needed to cause yielding is 5.4 kips, so these are all yielding there. Until you go to 14, then you become closer to the yield.

The maximum load exerted on the tube is

less than 5 kips if four or more tubes per quarter TSP are locked to the TSPs.

CO-CHAIRMAN WALLIS: Well, if it reaches this 11.7 kips, then presumably it pulls out?

MR. MAJUMDAR: The 11.7 that's the ultimate strength.

CO-CHAIRMAN WALLIS: Presumably it pulls out?

MR. MAJUMDAR: No, it doesn't come pull out. You have the materials ducked out these are our elastic analyses, so you need some displacement to pull it out. And the actual driving force is the TSP displacement. The displacement is limited, so the tube really won't -- even if there is no flaw --

CO-CHAIRMAN WALLIS: You're saying that all these tubes got pulled out with a force of less than 44-27 pounds or something like that.

MR. MAJUMDAR: Yes.

CO-CHAIRMAN WALLIS: So it didn't get to 5.4 kips?

MR. MAJUMDAR: No.

CO-CHAIRMAN WALLIS: -- 5.4 kips. I don't know what that's doing.

MR. MAJUMDAR: The thing is that that's the point -- that's the point that we're making that this kind of high tube pullout load cannot be --

CO-CHAIRMAN WALLIS: It would have pulled out by then.

MR. MAJUMDAR: -- pulled out by now.

CO-CHAIRMAN WALLIS: Yes.

MR. MAJUMDAR: What happens is it's not pulled out, it slips so that the constant load is slipping. So if you take that into account, you can see if the tube pullout load is five kips, then you get after that five kips --

CO-CHAIRMAN WALLIS: It never gets beyond that so nothing ever happens?

MR. MAJUMDAR: No. The question is the thing is that any load transferred to the top TSP gets transferred to the tube all the way down to the tube sheet. Because the load on the tube is pretty high, even though the first tube support plate does not see any ⌂p, the actual load under that portion of the tube is pretty high. So the load from the upper TSP gets transferred to the lower tube.

CO-CHAIRMAN WALLIS: And everything is hanging on at the bottom?

MR. MAJUMDAR: Yes. That's right.

Again, if you reduced the tube pullout load to one kip, then the maximum load gets reduced again and basically the axial load is already reduced proportionately.

Now, this is the tube pullout data, the only one I could get hold of is this non-dented tube pullout data from Dampierre-1. And they did an extensive tube pullout test, actually a number of tests 23.7, at room temperature, 12 at this, 9. They calculated these numbers. But basically what from this we assumed that the 4000 pounds, this number is our 95 percent confidence limit has an upper bound to pullout load and 2700 the mean force -- the average axial load transmitted from a TSP to a locked tube at 550 F.

CO-CHAIRMAN FORD: You said this is from a non-dented?

MR. MAJUMDAR: Non-dented, yes.

DR. MUSCARA: That partially answers the question you were asking before, the degree of locking without dents.

MR. MAJUMDAR: Yes. All these tubes in France, they are basically unlocked. They are not dented -- they are locked but not dented.

CO-CHAIRMAN FORD: I'm sorry. Could you go back to the Dampierre data? What are you trying to tell us here?

MR. MAJUMDAR: We believe that from this data that they conducted, this is the tube pullout data. This is the -- we didn't run this test, Dampierre run this. And there aren't many -- quite a few tests, actually, and from this test we designed this upper bound pullout tube pullout load on an average --

CO-CHAIRMAN WALLIS: But this is French data. Should we throw it out?

MEMBER SIEBER: On principle.

DR. MUSCARA: Can we mention this is not field data, this is a plant that was replaced. It's much like our Surry generator where we did a lot of work on our steam generator replace in service.

CO-CHAIRMAN WALLIS: Okay.

DR. MUSCARA: Dampierre was removed from service and then, you know, they measure loads in pulling the tubes, much like we did with Surry. But Surry had so much degradation that, you know, a 1,000 pounds was enough to pull the tubes apart because the support plates were breaking apart also.

MR. MAJUMDAR: But the French did a very systematic manner, so they keep the statistics on that.

CO-CHAIRMAN WALLIS: All their tubes

were stuck?

MR. MAJUMDAR: Yes, most of them. Yes.

DR. MUSCARA: They were stuck but not dented.

CO-CHAIRMAN WALLIS: So probably there were 2,000 or at least stuck tubes in their steam generator and there's no way that plate's going to move at all.

DR. MUSCARA: Right.

MR. MAJUMDAR: Okay. So basically the effect of an MSLB on flawed tube, up to now we have looked at the unflawed tubes, the whole reason for carrying out this study is to see the effect of the tube load on the stability of flaws existing in the upper tube sheet or mid scan region.

CO-CHAIRMAN WALLIS: Are primarily axial? What else would you expect? You're looking at the distortion of the plate or something?

MR. MAJUMDAR: The loads are axial, primarily axial, yes.

CO-CHAIRMAN WALLIS: What produces other loads?

MR. MAJUMDAR: Not bending, I mean there's no bending there. Bending stresses are negligible.

CO-CHAIRMAN WALLIS: On the tubes? You got twisting the end of them from the plate?

MR. MAJUMDAR: As I showed earlier, the bending stresses are small compared to the actual stresses. The tube support plate is very flexible. It's like a cheese, a swiss cheese.

Dynamic loads are not important, as I showed earlier. The effects of axial loads on the stability of both axial and circumferential cracks were considered. So the material properties that are used for average alloy 600 tubes at 286, yield of 40 ksi and UTS of 90 ksi.

Now first I considered the axial crack. The effect of axial crack on stability of actual cracks. And basically the bottom line is that axial cracks, and when you're pulling on the axial direction, the axial cracks hardly see the axial load. In fact, the crack opening decreases because of the pull on the tube due to force on the crack and in fact the tube burst pressure actually goes up.

So the axial cracks are basically benign in the presence of axial load on the tube.

MEMBER RANSOM: Again, these units of pressure ksi or thousands of psi, is that right?

MR. MAJUMDAR: Which one?

MEMBER RANSOM: Ksi is -- this is ksi, thousand psi.

MEMBER RANSOM: It means thousands of psi?

MR. MAJUMDAR: Yes. Yes. For example, this is half-inch long crack. We predict failure to get over 4600 -- 4400 psi.

MEMBER RANSOM: Okay.

MR. MAJUMDAR: And the tests actually show very close to that number.

But axial cracks are basically not to worry about. The problem will come on the circumferential cracks that are vulnerable to axial loads on the tube.

CO-CHAIRMAN FORD: Excuse me. Just before you get onto that, and that's even -- your previous conclusion is even more conservative because in fact you'll be confined by the tube sheet, the crude filled tube sheet around the axial crack, is that correct?

MR. MAJUMDAR: I'm telling you the axial cracks above the tube sheet are tube support plate.

CO-CHAIRMAN FORD: On the small amount is above the --

MR. MAJUMDAR: I am talking about the generator crack that is sticking outside the tube support plate or the tube sheet, or in the midst of those cracks, when you pull them, when the axial load is applied on that tube, those axial cracks may tend to close. And that's what this analysis is showing really.

DR. MUSCARA: And the crack on the support plate will tend to be locked, so it'll be even, as you say, more concerned about.

CO-CHAIRMAN FORD: Yes. Yes. Okay.

MR. MAJUMDAR: Now, this is the circumferential crack, for example, on top of tube sheet. And there is an EPRI/Zahoor model that will assumes that the tube is free to bend. And in reality there is a tube support plate that's there and does not allow the tube to bend. And basically what I'm showing here is that if you take the support effect into account, then crack driving force, which I am plotting here, the K_J is the crack driving force versus the axial load. If you assume the tube is free to bend it come up this way and then you go out this way. Very high crack driving force.

CO-CHAIRMAN WALLIS: Why is it going to

bend when it's being pulled?

MR. MAJUMDAR: It's really unsymmetric--

CO-CHAIRMAN WALLIS: It's unsymmetric --

MR. MAJUMDAR: Yes. Yes. It will bend.

MEMBER BONACA: I'm sorry. What are you representing there?

MR. MAJUMDAR: This is a tube, for example.

MEMBER BONACA: Tube. Okay.

MR. MAJUMDAR: That could be a tube sheet or where it's clamped down and then the tube support plate that supports the end. And you put a crack, a circumferential crack there and if you assume that the tube is unsupported, then you get a very high crack driving force, for example here. And we double up the model, Argonne showing that the effect of this small support, this support on the TSP can drastically reduce the crack driving force. And it is very conservative, you use this instead of that curve.

And this curve depends on the stand (UDTSFA) this stands between the tube sheet and the first tube support plate.

MEMBER BONACA: You said before that if without a locked tube, the maximum transverse displacement of the plate, of the first plate, would be .4 inches.

MR. MAJUMDAR: .4 --

MEMBER BONACA: Yes. Okay. Would that be the largest displacement? What I mean is that the other support plates will displace less, right?

MR. MAJUMDAR: Well, the other support plates --

MEMBER BONACA: I'm sorry?

MR. MAJUMDAR: The other support plates are slightly higher. The top support plates have higher pressure on them.

MEMBER BONACA: So they would displace more?

MR. MAJUMDAR: But their load gets transmitted to the lower support plates.

MEMBER BONACA: I understand that. That's exactly what I was trying to understand. What is the maximum displacement any given location on any support plate could experience, assuming it was unlocked?

MR. MAJUMDAR: Actually, the tube support plate displacement is not included in this plot I'm plotting here.

MEMBER BONACA: No. You had it on page

13, however.

MR. MAJUMDAR: Yes.

MEMBER BONACA: And that's the only one you're showing as far as displacement. And you've shown it for the first support plate.

MR. MAJUMDAR: Yes.

MEMBER BONACA: And you are telling me that's not the most limiting insofar as the displacement. So I was curious to draw --

MR. MAJUMDAR: But this could be, for example, this second tube support plate, that could be the third. So any tube span would be expressed like that, would be analyzed like that.

CO-CHAIRMAN WALLIS: It's free to bend, isn't it?

MEMBER BONACA: If you calculate a displacement of --

MR. MAJUMDAR: This is just for applying--

DR. MUSCARA: He is not asking about this one, he is asking in general if you calculated the plate displacement support plate by support plate?

MR. MAJUMDAR: Yes. The plate displacement goes into the final analyses and is automatically calculated.

DR. MUSCARA: So what was the maximum displacement that you noticed?

MR. MAJUMDAR: That is in the program, but I didn't wrote it down. As I said, it is free to bend as more tubes lock * into the number.

MEMBER BONACA: Was that the maximum?

MR. MAJUMDAR: Yes. That's at the maximum point. At the maximum point --

MEMBER BONACA: For each support plate?

MR. MAJUMDAR: Yes. Yes.

MEMBER BONACA: What about the different levels?

MR. MAJUMDAR: Depending on the pressure, that was for one psi was .4.

MEMBER BONACA: Yes, you should have -- which is the list and that was .4 inches. I thought that you would know or calculate also the most displacement without --

MR. MAJUMDAR: But that displacement was automatically calculated --

MEMBER BONACA: I mean a statement during the DPO was made that a steamline break can cause significant movement of the tube support plates.

MR. MAJUMDAR: Yes.

MEMBER BONACA: And we questioned what does it mean significant then as well.

Now, here we're not seeing it because we're assuming that there are a lot of locked tubes, and we can believe that. Still, I'm left with the question of what is the largest displacement I could imagine of the tubes before break. Visually it would help me understand what kind of solicitation are imposed on that single tube --

MR. MAJUMDAR: Well, if you remember that slide that I had with the .4 inches and put the tube in, maximum displaced reduced by .4 to a .05 or something like that. A big reduction.

MEMBER BONACA: That tells me that the tube --

MR. MAJUMDAR: One tube --

MEMBER BONACA: -- is working very hard.

MR. MAJUMDAR: Very hard, yes.

MEMBER BONACA: But in the location what about the highest plate, that was my question?

MR. MAJUMDAR: I don't have the number, but there will be -- that was included in the analyses that the load was transferred because of a displacement on the TSP.

MEMBER BONACA: I would like to have that information. Is it in the report?

MR. MAJUMDAR: Yes, the displacement of the tube support plate?

MEMBER BONACA: Yes.

MR. MAJUMDAR: Okay. I didn't pay too much attention to the tube support plate itself. I was concentrating more on the tubes.

MEMBER BONACA: Essentially is the information equivalent for the highest plate to the one provided on figure 13.

MR. MAJUMDAR: Okay. That's the highest pressure on there.

MEMBER BONACA: Yes.

MR. MAJUMDAR: If no tubes are locked --

MEMBER BONACA: That's right.

MR. MAJUMDAR: No tubes are locked that would be displacing by almost by 2 or 3 inches.

MEMBER BONACA: That's what I thought. From a ratio --

MR. MAJUMDAR: Yes. Multiple .4 by 7 psi.

DR. MUSCARA: Like I said, be careful. I know Westinghouse has done some evaluations on this. You assume that they're not tie bars?

MR. MAJUMDAR: No, the tie bars are there.

DR. MUSCARA: And you expect 2 or 3 inches?

MR. MAJUMDAR: No. The tie bars are not -- this is the maximum displacement. Three inches. There are the tie bars and the Zahoor is based on that.

DR. MUSCARA: I recall from the Westinghouse work that they were discussing more the range of a quarter of an inch displacement, even in the worst -- which was larger than that?

CO-CHAIRMAN FORD: What is the 50 and 1,400? What is the numbers? Is that the distance between the tube support?

MR. MAJUMDAR: Yes, that's the typical distance within tube support plate.

CO-CHAIRMAN FORD: And the next position where it is locked -- is that right?

MR. MAJUMDAR: That is the typical distance between the tube sheet and the tube support plate and the first one, or the first to second is almost 45, 49 something like that.

CO-CHAIRMAN FORD: You say 1400 is?

MR. MAJUMDAR: No. This is just to show

that our model if you put a very large length, then that model coincide with the Zahoor model. Their model is not providing any constraint.

CO-CHAIRMAN FORD: Okay. Okay.

MEMBER BONACA: Anyway, I would like to have that information. Because, I mean, if it is 3 or 4 inches, I will -- you know, I feel that's comfortable if I think about it.

DR. MUSCARA: Okay. But it's the same question issue. Because 3 or 4 inches, it's a clean tube which means there's no denting, there's no cracking so we're not concerned about exposing a crack.

MR. MAJUMDAR: But that strange with no denting, no tube lock. All is free to slide. There is no constraint to the motion.

DR. MUSCARA: We will look up the data.

MEMBER BONACA: For that kind of displacement, I mean it is free to pull. All of that to say is that, I mean, if the maximum displacement as you calculate was a quarter of an inch, then why we worry about the pull that you have on the single tube, should you assume that? Because at the most it would be very small. I mean, yes, I mean there is -- but if it is several inches, then you have to think about that single tube. And I know that there isn't going to be only one, but anyway--

MR. MAJUMDAR: But the -- the load on the upper TSPs, even though the lower TSPs don't see any ⌂p, the loads from the upper TSPs is transferred through the tube to the bottom.

MEMBER BONACA: Yes.

MR. MAJUMDAR: The tube see the whole load.

MEMBER BONACA: Okay.

MR. MAJUMDAR: And so a crack in a single tube lock in the first TSP, for example, I'm plotting here the failure axial load was to the circumferential -- through an angle that can be tolerated without being unstable.

So for an upper bound dynamic load of 4 kips, that's the forces upper bound -- the tube pullout load that we derive from * and the internal pressure loading induced to 1.2. This is the end cap loading that always happens when you apply an internal pressure. And through wall cracks less than 160 degrees. For example, this crack of 5.2 here. So any cracks less than 160 degrees will be safe.

If it is an average locking force of 2.7, it is easy to 210 degrees circumferential through wall cracks. And a single tube locked at all TSPs has a much higher dynamic loads but it cannot tolerate a significant circumferential flaw.

MEMBER BONACA: Okay. That makes sense.

CO-CHAIRMAN FORD: Joe, could you remind us as to when they're seeing circumferential cracks what is the normal circumferential angle? I mean, is there physically any reason of why it couldn't be 200, 300 degrees?

DR. MUSCARA: Yes, but there's a limit on what's acceptable with respect to plotting. We have seen -- degrees circumferential cracks.

CO-CHAIRMAN FORD: Okay.

DR. MUSCARA: Ken, do you want to add something?

MR. KARWOSKI: The normal practice for when a circumferential crack is detected is to plug it on the *. In general, there is no utility in the country that leaves known circumferential cracks in service. With that said, people do observe circumferential cracks after a cycle of operation, but in general -- and I can only give you generalities -- those indications are not -- you have to look not only at the circumferential extent, but also the depth. What they find is usually not structurally significant. The angles can vary. They're usually very short. You know, maybe more like 90, 180 degrees. There are some that are larger. But even when you get the larger circumferential extents, they tend not to be through wall.

And I think Saurin's analysis is based on a through wall flaw for 210 degrees. And in general we're not observing that type of flaw. So you can't just look at the through wall -- or the circumferential extent. You have to look at both.

DR. MUSCARA: Okay.

MR. KARWOSKI: And we're not finding 100 percent through walls flaws that are 210 degrees or even 180 degrees.

MR. MAJUMDAR: Now, the most benign cases is when all tubes are locked at all the TPSs. And that gives the axial load is only 1.6 kips.

CO-CHAIRMAN WALLIS: How does that get 1.6? I mean, you showed us before that when you get one you get --

MR. MAJUMDAR: Oh, these are all --

CO-CHAIRMAN WALLIS: -- fifteen and when

you get two you get ten, and you get four you get five. It's going down so rapidly I would think when you get them all locked, it would go down to essentially zero.

MR. MAJUMDAR: No. No. 1.6. We already--

CO-CHAIRMAN WALLIS: How can it be so big?

MR. MAJUMDAR: 1.6. We always had the end cap load there.

CO-CHAIRMAN WALLIS: It's the end cap load that does --

MR. MAJUMDAR: Always there plus the tube load.

CO-CHAIRMAN WALLIS: But the transient load is doing nothing.

MR. MAJUMDAR: No.

CO-CHAIRMAN WALLIS: The transient load is doing nothing.

MR. MAJUMDAR: That's right --

CO-CHAIRMAN WALLIS: So 1.6 is the end cap, which is always there.

MR. MAJUMDAR: No. 1.2 is the end cap load. So this .4 -- if you follow -- if all the TSPs are locked --

CO-CHAIRMAN WALLIS: Even when you have 3,000 of them stuck?

MR. MAJUMDAR: There's a lot of area there.

CO-CHAIRMAN WALLIS: Yes, but it's going down very rapidly from what --

MR. MAJUMDAR: Yes, but it doesn't go down really low, but it kind of flattens out.

CO-CHAIRMAN WALLIS: It flattens out?

MR. MAJUMDAR: Yes.

CO-CHAIRMAN WALLIS: They're all sharing the load.

MR. MAJUMDAR: Yes.

CO-CHAIRMAN WALLIS: But if it's 3,000 plus 1,000, it's a third of the load per tube?

MR. MAJUMDAR: Yes, but the tubes near the tierod are affected by tubes near the supports. All the tubes are not equal. Tubes near an existing support, for example, near a tierod, the tierod is already restraining the tube support plate, so that tube doesn't do much.

CO-CHAIRMAN WALLIS: Okay.

MR. MAJUMDAR: They're not all equal. Anyway, that load is so low that it can't even carry along the cracks. We already deduced that.

DR. MUSCARA: Through wall.

MR. MAJUMDAR: Through wall, yes.

CO-CHAIRMAN WALLIS: But the real thing is you only need a few tubes to stick in order to get within an allowable --

MR. MAJUMDAR: That's right. All we need is ten. If you can do ten, I'll show it here.

For example, a pullout load of 4 kips here, that's the upper bound pullout load. If you have ten tubes locked, then you are basically down below main load, 2 or 3 kips, and these are, tubes are elastic.

CO-CHAIRMAN WALLIS: So the main load is the fact that there is a pressure inside that gets attached to the bottom --

MR. MAJUMDAR: There's a pressure, yes.

CO-CHAIRMAN WALLIS: -- and it starts to push?

MR. MAJUMDAR: And this is actually -- yes. But this one is extruding end cap load. So this will be end cap load will be added on top of that. And the flawed forces is from here.

So the axial load decreases the increasing number of locked tubes.

CO-CHAIRMAN WALLIS: See how rapidly

that's coming down. You'd think with a 1,000, you wouldn't be above zero at all.

MR. MAJUMDAR: Well, there is some residue over there.

CO-CHAIRMAN WALLIS: Okay.

MR. MAJUMDAR: Also with the increasing number of locked tubes, the distribution becomes more uniform -- and also there is some negative pullout load, as I said before, because the pressure changes sine in the lower TSPs.

And basically, if you have four tubes locked, and then the actual load is about 7 kips maximum. If you have ten tubes locked for a quarter, then the maximum is about 3.

CO-CHAIRMAN WALLIS: And with 3,000 locked it's 1.6?

MR. MAJUMDAR: 1.4 with 2,000.

CO-CHAIRMAN WALLIS: Well, it says 1.6 here.

MR. MAJUMDAR: No, that's withdrawl actually. The same thing if the pullout load is 2.7, you get a reduction in the loads, in the actual load here and the tube pullout load.

Now, allowable crack angle from multiple locked tube, you plot the maximum allowable crack length in the tube support plate now. Now we're assuming the full MSLB and including the end cap loading. If you have only four locked tubes, we said there was 7 kips of actual load on the -- and the minimum cracking of 30 degrees on the high end.

If you have ten locked tubes, then you can follow a much, much longer crack length. It really gets -- the tolerance for circumferential crack and it goes up as you lock more and more tubes.

CO-CHAIRMAN FORD: Could I suggest, Joe, it's now 4:00. You are about to start a new subject and then go into a summary.

Could we take a quarter of an hour break at this time?

DR. MUSCARA: Sure.

CO-CHAIRMAN FORD: And also to consider whether to put off the iodine spiking until tomorrow, when you're starting on 3.3, with the artist's work, which is relatable to the iodine spiking? Does that sound a good plan, or do you want to do the spiking today?

DR. MUSCARA: The way today things are going and the topics we're discussing tomorrow, I think we'll have even more questions in discussion tomorrow.

CO-CHAIRMAN FORD: Even tomorrow. Oh, gosh. Okay.

DR. MUSCARA: So I think we need to try and stay on schedule.

CO-CHAIRMAN WALLIS: I think the spiking has two slides.

DR. MUSCARA: Well, I'm sure Michelle will be very happy to cover it in a few minutes and be finished.

CO-CHAIRMAN FORD: Okay. Well, let's take a quarter of an hour. Be back here at 4:15 and then we'll finish this and do the iodine spiking, too.

(Whereupon, at 4:02 p.m. a recess until 4:18 p.m.)

CO-CHAIRMAN FORD: Okay. We're ready to go into session again. We're about to go into the accepted crack growth rate analyses.

DR. MUSCARA: Peter, there's one point of clarification, maybe. We were talking earlier about some bending forces on the tubes at the lower section. Those were due to steamline breaking and cross flow forces on the tubes. So in fact, it was correct.

DR. KUPPERMAN: Let me just explain. I don't think I brought all the documentation. But I had forgotten because I did this model a while ago, when I built the model there is an area right down over here where you actually have the flow coming down over like this and then back up.

MEMBER SIEBER: Right.

DR. KUPPERMAN: So this area right here I actually did model across flow.

CO-CHAIRMAN FORD: Okay.

DR. KUPPERMAN: So you could calculate forces cross flows on the tubes in that area.

CO-CHAIRMAN FORD: Okay.

DR. MUSCARA: And I guess without spending a lot of time, the conclusion was that the forces were small enough that there was not much impact on bending --

MEMBER SIEBER: There is some kind of a blocking device down in that center channel. Is that modeled in or doesn't that make any difference. Tube lane blocking device. It's called a tube lane blocking device.

DR. MUSCARA: But I think those were removed back earlier inservice.

DR. KUPPERMAN: The drawings I had is

just straight.

MEMBER SIEBER: Just straight. Okay.

DR. MUSCARA: I think we had some problems with those and they were eventually removed.

MEMBER SIEBER: Well, I don't know.

DR. KUPPERMAN: So I'll check it out.

MEMBER SIEBER: I remember them being in there years ago. That's where the blowdown line used to be in that blocking device. You may be right. It is probably a second order effect.

MR. MAJUMDAR: So anyway, if you take in that, all those lateral pressure, the big bending stresses on this 777 psi. So they're small.

Okay. Up to now we have considered only a single application of the pressure pulse. The question is what happens if there are multiple peaks. But Bill Krotiuk's analysis show that there is not many, many peaks, there are at most two peaks and the pressure ⌂p goes down with time.

CO-CHAIRMAN WALLIS: This is a crack growth rate, da/dN?

MR. MAJUMDAR: da/dN, due to the pressure pulse.

CO-CHAIRMAN WALLIS: We'll we've seem

Ford data and other people's data that differs by orders of magnitude from the correlation.

CO-CHAIRMAN FORD: It's not binding.

CO-CHAIRMAN WALLIS: Really? Oh, it's GE data. I'm sorry. I thought Ford was associated with one of those transient data.

MEMBER BONACA: No, this is a cyclic data.

MR. MAJUMDAR: Yes, he's talking about crack growth data.

CO-CHAIRMAN WALLIS: Oh, I'm sorry. Okay. Yes.

MR. MAJUMDAR: Now, what is asked the question even if the pressure calculation shows there are no cycles, we are asked what if there were number of cycled pressure pulse, how would a crack respond to that cyclic load. So we computed the cyclic crack growth using this standard equation and using the ASME Code Section XI correlation. And stress in terms of the fracture we calculated using ⌂K for part two of circumferential cracks using the Zahoor correlation and through wall circumferential crack from the ANL correlation. We used that ANL correlation because without that effect the lateral support, the driving force gets pretty large. And for a span of 15 inch between supports.

So I said the crack growth was first done in the depth direction and then in the actual direction, in the circumferential direction until rupture was predicted. Rupture was predicted to occur when either the uncracked section that contains the crack reached a plastic collapse or by j1c failure, just by drop collapse instability. In most cases, the plastic collapse control the final rupture.

CO-CHAIRMAN FORD: The scenario is that the tube is pressurized?

MR. MAJUMDAR: Yes.

CO-CHAIRMAN FORD: You have the main steamline break and you got this whack and then a ringing?

MR. MAJUMDAR: Yes. Yes.

CO-CHAIRMAN FORD: Surely you did a higher R ratio than zero?

MR. MAJUMDAR: Well, what I did, there is a steady load and there is a cyclic load on top. But I said I consider steady load as part of the cyclic. That is more conservative than considering R factor. We apply that in -- this is really more conservative than using a smaller ampliture than is in R factor.

CO-CHAIRMAN FORD: Okay. And that's a conservative assumption?

MR. MAJUMDAR: Yes. Yes.

MR. MAJUMDAR: Because I'm putting the whole thing in ampliture -- in the range.

CO-CHAIRMAN FORD: Okay.

MR. MAJUMDAR: Now, if this is a through wall crack, if you look at this for different axial cycling axial loads, 7 kips was for the full tubes lock and 3 are 2 kips for the ten tubes locked. So when you only have four tubes locked, we can see the cycles to failure versus the initial through wall crack leg. To there is about 30 degrees or so can take several cycles, 8 or 9. If it's less than 30, then we can take even more. So actually that's what I'm just saying here, 75 cycles are required to grow the crack from 29 degrees instability of 30 degrees.

So the growth rate prior to instability on the order of .01 to .07 degrees per cycle. It is small.

Now, that was for through-wall crack. What if you have a part-through wall crack, usually part-through wall crack.

CO-CHAIRMAN FORD: Sorry. Could you just

go back to the previous one? I just want to make sure I understand this graph.

Do I understand it if you have a crack of 180 degrees or 150 degrees, two sigma, and you rang two or three cycles --

MR. MAJUMDAR: Yes.

CO-CHAIRMAN FORD: -- then if you had a axial load of 3 kip --

MR. MAJUMDAR: And this will be 4 kips.

CO-CHAIRMAN FORD: -- and you fail? Is that right?

MR. MAJUMDAR: Yes.

CO-CHAIRMAN FORD: Okay.

MR. MAJUMDAR: You have 4 kips cycling constantly and you have differing initial crack size, question is how many cycles would that crack take before it goes unstable.

CO-CHAIRMAN FORD: And failure is defined as the crack grows all the way around the tube?

MR. MAJUMDAR: When one cycle -- yes, this is the failure limit.

CO-CHAIRMAN FORD: Okay.

MEMBER RANSOM: What is failure? You already have a crack.

MR. MAJUMDAR: And then we are in the plastic, as I said, and the whole plastic collapse of the remaining ligament or J1C type failure --

MEMBER RANSOM: So you wind with a burst essentially?

MR. MAJUMDAR: No. Physically the crack go to burst, yes, a one cycle burst, immediately burst because in this case it will take 20 cycles -- more than 20 cycles to grow to instability side and then it will burst. Whereas in this case you are less -- starting with a smaller crack, take a 1,000 cycles to go and then rupture in a nonstable manner.

DR. MUSCARA: And you hardly have an additional cycle probability from the load?

MR. MAJUMDAR: In actual application there is only one cycle applied. But this is assuming if you applied repeatedly how many cycles could it take. So there's a lot of margin for crack growth there.

Okay. Now, if you have part-through wall crack, then there's some cycles you need to go through the thickness before it starts propagating in the axial circumferential direction. And in the high axial load, 7 kips for examples, you have here really plastic fracture mechanics where the tube is yielding, you don't buy much with the through thickness growth of the crack. That is an initially 80 percent through wall crack versus 100 percent through wall crack.

Now if it goes load/load, 3 kips and you take about 20 cycles to grow that crack through the thickness. And so you buy a lot of cycles, just propagating the crack through the thickness before it starts going along the circumference.

So basically, you get a lot of margin at low axial load. If you have ten tubes locked, then we have this kind of load. And if you have 14 locked, we have this kind of load.

CO-CHAIRMAN WALLIS: What cycles are you talking about here? I mean --

MR. MAJUMDAR: This is a crack that is not through wall.

CO-CHAIRMAN WALLIS: Yes, but what's with the cycles? What are the cycles --

MR. MAJUMDAR: We're assuming that we applying the same ⌂p that we applied --

CO-CHAIRMAN WALLIS: You have 20 steamline breaks?

MR. MAJUMDAR: Pardon?

CO-CHAIRMAN WALLIS: Isn't it just one

level. 20 steamline breaks? You're going to design this thing for 20 steamline breaks?

MR. MAJUMDAR: No, not 20 -- this is how many cycles will it take before the crack --

CO-CHAIRMAN WALLIS: It doesn't make any sense. This is a one -- very rare event with only one cycle.

MR. MAJUMDAR: One cycle, but --

CO-CHAIRMAN WALLIS: So who cares about many cycles?

DR. MUSCARA: Well, he's giving us a margin.

MR. MAJUMDAR: It's a margin. Supposing there was some calculation error or something.

CO-CHAIRMAN WALLIS: You think if you got a steamline break you will then say you don't have to inspect your steam generator very carefully and all that kind of stuff?

DR. MUSCARA: No. I think we're saying you assume there's one cycle, but what if you're running the calculation there were 20 cycles --

CO-CHAIRMAN WALLIS: Why would you ever want to do that?

MR. MAJUMDAR: You don't watch, they will burst.

CO-CHAIRMAN FORD: In this situation you're only going to do it once, but margin would have been the sigma, delta sigma you have to get to before you have complete rupture of the pipe, this $K1_j$, I would have thought. That was the value thought he was meeting a margin in this case. No?

MR. MAJUMDAR: Well in this case, the margin is in terms of the number of cycles that you would need to propagate an existing crack to the point where the crack size becomes critical and you get a --

CO-CHAIRMAN WALLIS: Seriously, this is 20 steamline breaks you're talking about?

MR. MAJUMDAR: No. Same tube --

CO-CHAIRMAN WALLIS: I think if you had two steamline breaks, they'd probably shut down your plant.

MEMBER SIEBER: No, it's a green. I had seen a calculation at one time where the tube support plates were treated as a membrane which had an oscillatory effect. And if that were to occur, you could rack up some cycles before blowdown is completed. And so that's where this kind of a calculation becomes important to me.

MR. MAJUMDAR: Yes. By the way, the

water is sloshing back and forth, they could have had more cycles -- this has been existing or something. Even it did --

CO-CHAIRMAN WALLIS: But this analysis is based on one thing. And there's no sloshing --

MR. SHACK: The DPO Subcommittee was worried about cyclic crack growth under some sort of ringing loads. So we didn't have any idea what ringing loads to you, so we picked the biggest ringing load we could think of: the pressure pulse at the main steamline break.

CO-CHAIRMAN WALLIS: But it doesn't --

MR. SHACK: And we demonstrated there was margin.

CO-CHAIRMAN WALLIS: It detenuates in --

MR. SHACK: Yes, it does. But we were trying to address the ACRS Subcommittee. We didn't know what they had in mind, but we were going to take the most conservative analysis we could come up and demonstrate to them there was margin.

MEMBER SIEBER: During the DPO presentations, we were shown --

CO-CHAIRMAN FORD: Boy, that guy is bullshit isn't he?

MEMBER SIEBER: An analyses of tube

support plate that had nodes in it in cyclic loads. So that's where the question came from. And this is the answer.

MEMBER BONACA: No, what he talked about was 4 tubes locked, he's assuming that they are locked.

MR. MAJUMDAR: Yes. The loads would depend on whether they are locked; whether 10 tubes are locked or 4 tubes are locked.

MEMBER BONACA: They're not all together? I mean, because --

MR. MAJUMDAR: Yes. The tubes when I said there are 4 tubes locked, they're in a local region. It's not one here, one there, one there. It's in local region.

MEMBER SIEBER: And you're only analyzing the quarter --

MR. MAJUMDAR: The quarter of. So it's actually 16.

MEMBER SIEBER: So there's 16.

MR. MAJUMDAR: Actually it's 4 times that. Yes.

MEMBER BONACA: Okay. All right. But if you have one, you got four?

MR. MAJUMDAR: Yes.

MEMBER BONACA: If you got 4, you got 16?

MR. MAJUMDAR: Yes.

CO-CHAIRMAN FORD: What I'm hearing being discussed here is that you have developed the methodology for determining the structural integrity of these faulty tubes under various impulses. And so you can apply it to any different definition of margin that you may want to.

I noticed in the next slide you're going into conclusions.

MR. MAJUMDAR: Right.

CO-CHAIRMAN FORD: But I was going to ask item i, 3.1.i is conduct confirmatory tests. Are there any confirmatory tests to back up --

MR. MAJUMDAR: As I say in my talk that we did some tests on bending, so we know the bending stress on the two blocks of pressures. So we got a rather extensive series of tests where we supported the tube on 15 span and then put cracks next to one span, one welded in span and pressurized it. Did the tests until rupture, the tube ruptured and showed that in those tests bending stresses -- you got the bending where hanging load from the middle of the tube so the crack was subject to the bending stress as well as the pressure, axial load in the pressure.

All cases that we ran showed that the bending stresses had very little effect on the bust pressure. We had both subcrack and actual crack.

CO-CHAIRMAN FORD: Now is that the only confirmatory tests that has been done on this model?

MR. MAJUMDAR: That is the only test we did.

CO-CHAIRMAN FORD: And we haven't heard that? I mean, this is something --

DR. MUSCARA: No, because you haven't seen -- he just mentioned that he had done the tests.

CO-CHAIRMAN FORD: Oh, I see. You haven't even seen it?

DR. MUSCARA: The results are published in the report that was used to run -- have we closed out this action, Jim? So those results are published in the report.

MR. MAJUMDAR: So you are preparing a NUREG report on that. We just submitted it. Yes.

DR. MUSCARA: And I guess maybe the other comment I would like to make, the reason we only did the bending test validation is because the methodology we have been developing over the years, it's already been proved and benchmarked and tested on the predictions of tube burst and failures and ruptures. The one item here we've done is the additional bending. And so that, you know, we came up with the analytical method and then ran some tests to show that he could predict the test results.

CO-CHAIRMAN FORD: I guess why I keep hammering on is this so simple that this is a no never mind? I mean, it is time and time again we've been bitten in the behind by someone coming along saying something occurred which we hadn't predicted. And this is why I keep asking: Have there been confirmatory tests? And what I'm hearing you say is, yes, you've got one set on bending and there's a whole pile of other stuff to back up this methodology. Is that correct?

DR. MUSCARA: A lot of the analytical stuff he's shown you has been developed over the last two programs, ten years or so.

CO-CHAIRMAN FORD: Okay.

DR. MUSCARA: And it's based mostly on testing and analyses.

Now what program is it --

MR. MAJUMDAR: These were done with answers, and this was done almost a year back. More than a year back.

CO-CHAIRMAN FORD: Okay.

MR. MAJUMDAR: Using the elastic analyses, so they're pretty standard. And this is the best -- if one thing we know about stress analyses, it we need an elastic analysis.

MEMBER BONACA: So your results are not inconsistent with the claim that we have in DPO that steamline break could result in fact in tremendous forces and booming sounds and things of that kind and they told us there was -- because of that they're going to fail a lot of steam generator tubes now. What I see here is that you have in fact significant displacement of the plates, and you have, potentially, but the tubes are able to withstand or to limit those displacements without failures. I mean, they're doing things that are not inconsistent.

DR. MUSCARA: I think the analysis showed that the forces weren't that large. The forces were not that large.

MEMBER SIEBER: But there is a conclusion that if you block just one tube, that

that tube will fail.

MR. MAJUMDAR: Yes. Yes. At least it's a possibility to take circumferential cracking very limited.

CO-CHAIRMAN WALLIS: But to make a tube fail, you have to make some extreme assumptions?

MR. MAJUMDAR: Yes. Yes. That's right. Plus get -- not on displacement to rupture tube. We need a lot of displacement. If you don't -- there were no crack in it, it will be impossible to rupture the tube because we need displacements in addition to loads.

MEMBER BONACA: The forces will not be that large, but it will be sufficient to bend, I mean unless there was locking, to bend those plates.

MR. MAJUMDAR: No, the plates will bend.

MEMBER SIEBER: That's for sure.

MEMBER BONACA: I mean that's a heck transient. I mean --

CO-CHAIRMAN WALLIS: But they won't because 3,000 tubes are locked into them. That's what the difference could be.

MEMBER BONACA: I agree with that. For the first time, I realize that cloud good, for some reason.

CO-CHAIRMAN FORD: Joe, just to come back to this confirmatory tests, in the NUREG-1740 I think there is a statement in there to say that the confirmatory tests on this task are crucial. That particular task, 3.1.i has been completed you say. And I did I hear you say it closed out? Does that mean that there will be no more confirmatory tests done on that, in this area?

DR. MUSCARA: That's right. I think we concluded that the loads were small enough, and in particular when it's shared by more than one tube, that there wasn't anymore need for refinements for additional tests.

I mean, the reason for the tests was to benchmark an analytical procedure, and we've done that. So we're able to predict the test results before we ran the tests.

CO-CHAIRMAN FORD: Yes. And subtask J and K, K has not been completed. It's not due to be completed until next year sometime, 2005?

DR. MUSCARA: That's right.

CO-CHAIRMAN FORD: I guess the reason why I keep on asking these questions is that we keep hearing the words closed out. That doesn't mean to say that work stops, does it?

DR. MUSCARA: I think the inputs pretty much for this task are finishing up.

CO-CHAIRMAN FORD: Okay.

CO-CHAIRMAN WALLIS: Well, it's closed out when NRR has enough information to make a decision, isn't it? Otherwise you could go on working forever.

MEMBER SIEBER: There you go.

DR. MUSCARA: I think we've closed out the pieces we need to develop from the research side. Now this information is going to be taken at NRR with Steve Long to conduct his analyses. And that point, based on whatever results he gets, we'll conclude whether the issue is closed or not.

MEMBER SIEBER: Sooner or later you have to close out the DPO, unless this is the way you're going to conclude it. So, so far there hasn't been anything presented that would invalidate the holding space alternate repair criteria.

CO-CHAIRMAN FORD: Let me ask another --

MEMBER SIEBER: So that's in effect, and remains valid.

CO-CHAIRMAN FORD: Let me ask my other Commission members, being new to this particular item. Since we wrote a report on the DPO issues, are we part of the closeout decision process, the ACRS?

Tom?

MEMBER KRESS: What did you say?

CO-CHAIRMAN FORD: Yes. I was asking since we wrote a NUREG on the DPO process, are we part of the formal closeout decision process or not? I have no idea what the --

MEMBER KRESS: I would think we are.

CO-CHAIRMAN FORD: No.

MEMBER KRESS: You know, if we say things like we shouldn't close this out yet and the Commissioners agree with us, then we're part of it.

DR. MUSCARA: Yes. I think the ACRS report we've developed the action plan. ACRS reviewed that and said yes this will address our recommendations and concerns. Now some of the issues have become generic issues.

CO-CHAIRMAN FORD: Yes. Yes.

DR. MUSCARA: In that process you will hear about how it is resolved. And we have a couple of items that are generic issues which are also part of the DPO that I think were developed in the database to close them out, but we haven't gone through the formal process to close them out including going through the ACRS. And one of those issues is the steamline break issue.

CO-CHAIRMAN WALLIS: But if the regulatory part of this agency were to write a letter to all these utilities and say we have decided that you are allowed to assume 100 tubes are stuck because they're pretty darn sure that it's more like a thousand, that would close out everything, wouldn't it, as far as this part of the work is concerned? Because nothing is going to happen.

DR. MUSCARA: Well, in my mind I think that this is not an issue.

CO-CHAIRMAN WALLIS: But the whole thing is it depends on how many tubes are stuck?

DR. MUSCARA: That's right.

CO-CHAIRMAN WALLIS: Whose going to decide how many tubes are allowed to be stuck?

DR. MUSCARA: Right. And I think all we can do is base it on engineering judgment and what's reasonable. I think if you have a degradation process it doesn't effect just one tube. And it doesn't effect just a handful. Often it effects many tubes. So we have a degradation process, many tubes are locked and it's not a problem. If we do not have a degradation problem, the tubes aren't locked and there's no load transfer to the tube.

CO-CHAIRMAN WALLIS: Somewhere between this possibility that there might a period of time when you had concern?

DR. MUSCARA: Not in my mind. At least, you know, very small. Again, I don't see a process just happening on one tube alone.

CO-CHAIRMAN WALLIS: But it would have to be a new steam generator where the cracking process somehow proceeds so rapidly that you get big cracks before you stuck the tubes to the plates.

DR. MUSCARA: Yes. And, again, I don't know how -- if you're talking about the support plate, the cracking that occurs because the support plate gets cruded up and the chemistry gets concentrated and then it cracks, so if it's happening to one tube --

CO-CHAIRMAN WALLIS: So it's really stuck up?

DR. MUSCARA: -- it's happening for many tubes.

CO-CHAIRMAN WALLIS: So it's already stuck before it cracks? So forget it.

MEMBER SIEBER: I think the flaw here is

the fact that nobody wrote down what this assumption has to be and justified it. Even if you justify it on the basis of engineering judgment, it's not written down. It's left to the reader to say, to input that extra piece of information, you know.

DR. MUSCARA: Yes. I mean what's written down is strictly recording the results.

MEMBER SIEBER: That's right.

DR. MUSCARA: When one now looks at this issue, to close it out, I have to make an assumption--

MEMBER SIEBER: But to close out the issue you have to make an assumption. You have to make an assumption about how many tubes are stuck and what's the reason.

DR. MUSCARA: Precisely.

MEMBER SIEBER: And so we couldn't close this out until somebody makes that assumption and says here's the basis for our judgment that this is okay.

DR. MUSCARA: Yes.

MEMBER SIEBER: It seems to me in the question of how do you handle this, the NUREG report that we wrote is no different in my mind than the letter that we write to the staff for conclusions and recommendations and the staff writes back and says we accept this, we accept this, we accept that. We've done this work, here are the results. And they send us something back which all of this is part of that. And if we don't like it, we write them back.

DR. MUSCARA: Yes. And I should point out that the action plan, again, is a living document. We change it when we feel the need to change it based on recent results.

MEMBER SIEBER: Right.

DR. MUSCARA: We can make a change in it if we have a recommendation that's warrant in making a change.

CO-CHAIRMAN FORD: Do you want to go through your conclusions or do you want to take those as read?

MR. MAJUMDAR: Well, if we can just quickly go through that.

CO-CHAIRMAN WALLIS: I think most of them have already --

MR. MAJUMDAR: Yes. Basically the bottom line is at the end, I guess. We don't think there's any need for additional TH analysis --

CO-CHAIRMAN WALLIS: Of course, the real bottom line is there's no need for any additional fracture mechanics at this time.

MR. MAJUMDAR: Yes.

DR. MUSCARA: By the way, I'm not sure how this last page --

CO-CHAIRMAN WALLIS: I mean, you haven't evaluated the quality of the thermal hydraulic analysis? How do you know there's --

MR. MAJUMDAR: We saw that ⌂p from the industrial analyses that gave us almost the same--

CO-CHAIRMAN WALLIS: No need for additional work either in thermal hydraulic analysis or in --

MR. MAJUMDAR: There is no thermal hydraulic analyses, there's no need for fracture analysis.

CO-CHAIRMAN WALLIS: Okay. That's what you think is the case?

CO-CHAIRMAN FORD: I would suggest that what you're really talking about here is structural integrity on the fracture mechanics. We're not talking about -- you're using thermal hydraulics in some cases, but you're not looking at all the thermal hydraulics?

MR. MAJUMDAR: No, I'm not looking. I'm just looking at the answer that came out of the thermal hydraulic analyses.

CO-CHAIRMAN FORD: Sure. Which is only a part of the whole.

CO-CHAIRMAN WALLIS: Now we have a form to fill in in our packet here? Evaluation of Training.

DR. MUSCARA: We're trying to find out how good this course is.

CO-CHAIRMAN WALLIS: Evaluate it.

CO-CHAIRMAN FORD: Well, thank you very much, indeed.

CO-CHAIRMAN WALLIS: Shall I throw it away?

DR. MUSCARA: Yes, it's not meant to be there.

CO-CHAIRMAN WALLIS: Well, let's see what it says.

CO-CHAIRMAN FORD: Joe, are you going to continue leading the final one today on iodine spiking

DR. MUSCARA: Yes. I think I will Ms. Michelle Hart, who is the lady to talk about what's been going on with the iodine spiking issue.

MS. HART: My name is Michelle Hart. I work in the NRR staff in the division of system safety and analysis. And I'll be talking to you about where we are on item 3.9 the iodine spiking.

As you know, in the DPO response the ACRS Ad Hoc Subcommittee asked that we look for a more technically defensible position on iodine spiking. And the first item on the steam generator action plan was that we go back and we look at the data that already existed that was used before and determine what that says, what that says to us.

And we've already completed that. And the next item was to develop a response to the ACRS recommendations, and that is almost complete.

We did look for more data on the iodine spiking phenomenon for the steam generator 2 rupture and main steamline type events. None additional was found. So we went back to *Adams and Atwood, Adams and Sattison* and we looked at the raw data. We didn't look at the adjusted data that was used in the conclusions. We looked at the data that was taken from the plants' logs, pre and post trip iodine concentrations in the coolant.

When we looked at the raw data we do see that there is a higher spiking indicated, you know post-trip iodine concentration in the coolant for very small activity concentrations measured pre-trip.

We did not see that there was a clear dependency on the rate of iodine spiking appearance based on the pre-incident iodine activity.

MEMBER KRESS: Well, let me ask you about that. The Ad Hoc Committee took that same database and found a clear dependency. They have a curve and they fit -- took the 95 percentile and had a clear dependency on the pre-activity concentrate rate. Did you just ignore that or did you decide it was all right, or what?

MS. HART: WE did not ignore that. We looked at the combined data and we eliminated what were thought to be repeats of the same accidents, you know, between the two studies.

And when we graphed the data, basically it looked like there were two lines. There was like a lower slope and then there was an upper slope.

MEMBER KRESS: We did the same thing, the Ad Hoc Committee, and we decided an appropriate regulatory position would be to take the one that gave you the worst conditions.

MS. HART: Right.

MEMBER KRESS: Because you don't have a mechanistic explanation for the reasons for these different populations.

MS. HART: Right.

MEMBER KRESS: So we took the worst one.

MS. HART: Right.

MEMBER KRESS: So we had a clear dependency. We didn't understand some of the data, but we were able to use a regulatory type look and it seemed to me like that would be the way you ought to go.

MS. HART: We determined because there was that unknown quality; why are there two lines like that? We didn't know what that meant.

MEMBER KRESS: Well, we didn't either. We didn't either. We speculated that it might have been because it wasn't failed tubes that the constant line was some sort of trapped uranium or something.

MS. HART: Right.

MEMBER KRESS: But we didn't go any further than that. We said well, since we don't know, we'll use the regulatory -- the way the regulators always do and say we'll use the one that gives us the worst.

MS. HART: Right.

MEMBER KRESS: Which you apparently

didn't do?

MS. HART: I do understand that.

MEMBER KRESS: Okay.

MS. HART: WE didn't determine that. We didn't see that there was a reason why the dependency existed. And we didn't see that --one of the questions was that you get much higher spiking at very low activities. And we didn't see like, you know, a change in the curve or anything. We didn't dispute your findings or anything like that. We just didn't go that direction.

As you know, we currently use a mass balance model. We don't know the mechanistic reasons behind the spiking itself. And we determined that for these very low preaccident iodine concentrations, that you get an equivalent to what our current standard assumption is, one like a Ci/gm with a 500 times spiking for 8 hours, that you would need a spiking factor of 50,000 times.

MEMBER KRESS: Yes, I think that's reasonable approach. Let me ask you something about that particular bullet.

If you use the 1 uCi/gm, which is sort of a tech spec value and the 500 spiking factor that you kind of use with that, how close are you to the dose limit?

MS. HART: It does depend on the site, definitely it does. But for a site that is right up on the limit, we have a lower acceptance criterion, it's not the full Part 100 for full Part 50-67, it's ten percent of that. So you would be 30 rem thyroid for the traditional source term, and 2.5 rem teddy for the alternative source term.

MEMBER KRESS: How close were you to that?

MS. HART: Well, that is this, that is that 31 thyroid.

MEMBER KRESS: So you're close to a factor of ten below it?

MS. HART: Right, below the Part 100 limit. And that's what our regulatory acceptance criterion are for these plants. They all have to meet that.

MEMBER KRESS: Well, if you take the 1 uCi/gm and the curve that we used to get the spiking factor --

MS. HART: Right.

MEMBER KRESS: -- and you assume 500 to get something like a thousand. If you use that, would that still put you up to the limit?

MS. HART: For the same plant with the same meteorology, no, you would above that regulatory limit. But you would not be above the Part 100 limit.

MEMBER KRESS: Well, I'm beginning to worry now that your margins -- if you use reasonable values for these spiking limits -- let me ask you, your 500 times, I recall included the ⌂p correction because the main steamline break has a faster and bigger ⌂p than the database has.

MS. HART: Right.

MEMBER KRESS: And you used the square root kind of maximum ⌂p or something like that?

MS. HART: To tell you the truth, I am not sure. Nobody was able to tell me the providence of the 500, unfortunately, before this meeting.

MEMBER KRESS: Well, the question I was going to ask is if you used square root of the ⌂p and a reasonable spiking factor out of our correlation, and your dose calculation, how close then would you be to the acceptance value? And another question I was going to ask is what's the basis of the square root of ⌂p? I'm sure that's the speculation that the velocity -- that ⌂p is a promotion on velocity square across the clad or something. But I'm not sure I know the basis of the square root of ⌂p. And is it just an unsubstantiated hypothesis or have you made tests to show that -- or you have data to show that this really would be the case?

MS. HART: To tell you the truth, I don't even know about the square root of ⌂p myself.

MEMBER KRESS: I'm really concerned about your iodine spiking because it looks like it hasn't been -- that our problems with it haven't been really addressed very well. I'm really concerned about that. And it also looks like that you could possibly be bucking up against the dose limits if you use numbers that I think probably are reasonable based on the correlations that we presented in the Ad Hoc report.

MS. HART: I don't know if that is the case. I can say that when we looked at the data that was given, of course it doesn't relate to main steamline breaks. And, as I said, we didn't --

MEMBER KRESS: It's the transient.

MS. HART: Right. We couldn't find any. There's been nothing done on that.

MEMBER KRESS: We all recognized that, that it's only --

MS. HART: Right.

MEMBER KRESS: You know, I haven't seen this reevaluation of the database. All I have is what we did when we had back when the DPO was being looked at. And I didn't see much you could with that except use it as is. I don't know what your reevaluation did, but I'd kind of like to hear more about what you did to reevaluate the database.

MS. HART: The reevaluation looked at the pre-imposed accident iodine concentrations. And there was some work done to try to determine what the iodine appearance spiking factor would be, try to back that out. And that effort was abandoned and we went purely based on the before and after iodine--

MEMBER KRESS: Concentration.

MS. HART: -- concentration. And based that -- and looked at how our current model does that.

MEMBER KRESS: Trying to get the rate and spiking factor?

MS. HART: Right. And looked at our current mass model -- mass balance model and determined that it was conservative from our point of view, that for the --

MEMBER KRESS: I'd have to see that before I can comment on it. And that you a different view of the correlation between the spiking factor and concentration when you did that?

MS. HART: It didn't really give us an idea of what this -- you know, if there is a spiking factor based on the appearance rate. It didn't really show us what that correlation would be. It would show us -- let's say, for instance, you're talking about the trapped uranium appearing or trapped iodine actually appearing. Iodine coming out through a, say, a break in the fuel or something. The appearance rate spike would not be -- would not capture that. And for the very low concentrations you have a very low appearance rate. And so you get one atom of iodine out, that's going to cause your appearance rate to look very huge.

And so when we looked at it from that perspective, it's not --it's not going to really show you the real picture.

MEMBER KRESS: -- by the fact that it's low concentration in the first place.

MS. HART: Right. Right. Right.

MEMBER KRESS: These slides don't really do it for me. I really don't understand why you didn't make some use of our look at the spiking factor versus concentrations because --

MS. HART: Well, the direction we were given was to go out on our own and look at it from our perspective.

MEMBER KRESS: Yes. I understand that.

CO-CHAIRMAN WALLIS: Well, if you look at your conclusion slide, the next one, it says "The staff thinks that the current modeling regime is conservative."

MEMBER KRESS: See, and I'm questioning --

CO-CHAIRMAN WALLIS: And I think that the ACRS Subcommittee looked at the data and said maybe this isn't conservative and you need to be more careful. And I don't see you've refuted their claim there. You seem to have a sort of an argument about why it's conservative, but it hasn't really refuted the analysis that my colleagues did. So this looks like another one of these presentations which is all words and no analysis or no evidence, or something.

I mean, how do you refute the Subcommittee's conclusions that maybe there was a problem here?

MS. HART: We looked at the data and we didn't think there was a problem.

CO-CHAIRMAN WALLIS: Yes, but that doesn't tell me anything. It doesn't tell me how you thought.

MR. DOWNIG: This is Bob Downig, the section chief for the section that Michelle's in.

I think that if what you're hungering for is the underlying analysis, I think --

CO-CHAIRMAN WALLIS: And the rational.

MR. DOWNIG: -- we'll be providing the plots and so on and so forth and what was done.

As far as the approach, as I understand it the alternative approach is not a mechanistic one, it's what you termed a regulatory approach taking the worst case looking at the data, drawing the line as high as you could, or whatever, as opposed to where we draw the line. I just want to understand what the alternative is that we're bouncing up against.

MEMBER KRESS: Yes. We thought if we disregard anomalous part that didn't -- and when we correlated it with the -- and took the 95 percentile, we said we can find for different concentrations of iodine at the 95 percentile level, we think there's spiking factor. You take that spiking factor and you say now do something about the ⌂p. And we had no other way to scale it with the ⌂p other than what you did. So we went ahead and said well let's take that and multiple it by about a factor of ten.

If you take our value for the 95 percentile concentration at the one uCi/gm level, take that spiking factor, adjust it by this factor of ten, it looks to me like you might get a dose that exceeds the 10 CFR 100.

I don't have a dose calculation either, and if that's plant specific, so I had to kind of guess at that possibility. But it looked to me like that would be something you might want to do. And it looked to me like you might become opposed to the dose limit. I don't know if this is an appropriate approach or not, but that's what was bothering me about the whole thing.

MS. HART: Okay.

CO-CHAIRMAN FORD: Okay?

We'll be discussing tomorrow you know, some of our recommendations at our meeting, which I don't doubt, on Thursday that is -- presentations on Thursday. And I don't doubt that this will be one of the issues at that meeting again.

Are there any other comments from the members on today's issues? We'll be talking about them overall tomorrow, at the end of the meeting tomorrow, but --

CO-CHAIRMAN WALLIS: About the presentations, we say this over and over again and sometimes the staff will listen. But slides that are full of words don't help us very much. But one or two slides with really good data and evidence helps tremendously. Why don't we have presentations that have data in them, pictures, points on graphs or analysis of something that proves the point instead of all these words? And we've said that many times before.

CO-CHAIRMAN FORD: Well, we see that the data, those that did conform to that did better.

Joe, all the presenters, thank you very much, indeed, for the presentations today.

Look forward to seeing you all at 8:30 tomorrow. Thank you.

We're adjourned until 8:30 tomorrow.

(Whereupon, the Joint Meeting was adjourned at 5:04 p.m.)