MR. ALLEY: EPRI does this for us.

MR. POWERS: Oh, okay.

MR. ALLEY: One of the few facilities to do this is at the NDE Center. So we're able to do that there. But we are very confined as far as the size of the flaw. I think its axial length, and I'm not sure what volume we're able to accommodate, but it's --

MR. ROSEN: If it's something to 45,000 psi, it's too big.

MR. POWERS: There's a guy up in Worcester, Massachusetts that uses a bell off one of the U.S. battle ships, and so it has either a 14 or a 16 inch bore on it for doing both HIP and CIP. So if you need a bigger one, there are bigger ones around.

MR. ALLEY: Yeah. CIP works well for us. We found the HIP actually will fuse some of the flaw characteristics back together again. So sonically we're kind of locked into the CIP process.

MR. ROSEN: After all of this work, you've gone back and fused --

MR. POWERS: It might make them look realistic.

MR. ALLEY: That would be debatable.

Okay. The next slide is going to show the

mock-up that was designed for the eddy current inspection, and here we just have a plastic representation of the vessel and the nozzle, and we've machined into this receptacles, square receptacles for these coupons. We're able to grow these coupons in the laboratory.

As I mentioned before, they contain actual SCC cracks. Then we're able to take these coupons and imbed them in this sample and then run the eddy current probe around the sample. This allows us to mix them up and change them around and keeps some blindness to these tests.

But we are actually using SCC samples for the eddy current.

MR. ROSEN: So that's fairly clever.

MR. ALLEY: We have our moments.

MR. MATHEWS: Except these weld beads are straight instead of curved, you know.

MR. ALLEY: Yeah.

MR. MATHEWS: But it is a way that you could shuffle things around and give each guy a different test.

MR. ALLEY: We're able to vary the width and the length and the orientation of the flaws this way because we grow them in the laboratory, and then

we can transport them over to the sample. We don't have to worry about trying to grow them in that sample, which would be a very difficult task to do.

The next slide just shows the close-up.

CO-CHAIRMAN SIEBER: That makes an interface though of materials, right?

MR. ALLEY: Yeah, but the --

CO-CHAIRMAN SIEBER: It's very hard to get a sonic.

MR. ALLEY: This is an eddy current.

CO-CHAIRMAN SIEBER: An eddy current.

MR. ALLEY: Yeah. So we're just interested in the service, and the flaws, if you'll put the next slide up, I'm not sure you'll be able to see them in the view, but we can show it and see.

We've got -- well, yeah. See, there's a flaw right there, which is in one of the beads of the weld. The flaw is actually contained right in there. So we're able to imbed that from the eddy current. You know, we can just window in on that area and test that coupon.

MR. ROSEN: Is that difficult on the surface that you see in the field?

MR. MATHEWS: It's pretty rough.

MR. ALLEY: It's pretty rough actually.

There's probably some vessels out there that aren't that rough, but most of them we find the condition is much better than that. Some of them have been ground smooth. There are just various states of condition on these J groove welds, which is an issue we continue to wrestle with.

Okay. You can change it to the next slide. We'll start going over some general rolled up results from what the vendors were able to accomplish.

Again, for Vendor A, if we look at the blade probe UT or the penetration tube, now, blade probe, again, is one transducer on a very flexible metal stick. It's actually split up the side of the nozzle. So we have to combined different blade probe results which I'll show you a table of that in a moment. but we were able to detect flaws it raised from 15 to 100 percent through wall were detected as part of this process.

When they're oriented perpendicular to the beam direction, we're able to detect flaws 15 to 100 percent through wall when they're oriented parallel to the beam direction.

MR. WALLIS: Now, does that means you do not detect them if they're 12 percent or just you didn't investigate that?

MR. ALLEY: No, they were not detected if they were less than --

MR. WALLIS: They have to be bigger than --

MR. ALLEY: That's correct. That was the minimum detectability.

MR. WALLIS: Is the resolution limit.

MR. ALLEY: That was the minimum detectability for those flaws. We had flaws in the blocks that were smaller than that that were not detected.

Okay. Now, it's important -- excuse me?

MR. POWERS: How is the probe coupled?

MR. ALLEY: It's just water.

MR. POWERS: You immerse --

MR. ALLEY: No. They've got a little squirter that comes at the back of the probe and just sprays the coupling on the nozzle to the blade probes.

Now, the rotating probes are usually done with a boot or something on the bottom that flood the tube. It's important to note here one of the things we wanted to try to understand better was just beam direction orientation because with blade probes to go in and try to do the same level of examination you would do with the rotating probe, which has seven or

eight different probe packages on it, you would have to do eight separate exams.

So you begin to swap off what you're able to accomplish with a given exam. Are you looking for circumferential flaws or axial flaws, and are the detection capabilities of one flaw for a flaw that's not oriented right for that direction of sound? You like for the sound to come in perpendicular to the flaws all the time, but what happens if it's coming in the same direction of the flaws? What's our detectability?

There's two philosophies in doing this, and again, this gets to the utility specific part of this. It's certainly the prior information we had on MRP 75 said you've got to have an axial flaw before you can have leakage to the annulus and get a circumferential flaw.

So some utility said, "I'm going to go look for axial flaws. I'm going to look in this direction to find the large axials because if I have no large axials I can't have circumferential."

Other utilities have said, "Well, I'm going to go in and I'm going to look for the safety significant circumferential flaw." So they want to look in this direction.

So immediately the question is: well, if you didn't find any circumferential flaws, what kind of detectability do you have for the axial flaws looking in the other orientation? That's part of this mock-up. That's why you see the notes in here indicating the flaw direction and the beam direction.

So we found that we had very good detection capabilities with the off axis probe. So the circumferential probes did fairly well. For the axial flaws and the axial probes, did fairly well with the circumferential.

CO-CHAIRMAN FORD: In the new revision of MRP 75, you start to calculate the amount crack to grow; you assume that the crack grows 15 percent, through wall thickness.

MR. MATHEWS: That would factor into the reinspection frequency. Where do you start and how long can you grow?

CO-CHAIRMAN FORD: That's right.

MR. MATHEWS: And I'm not sure 15 would be the number we'd use. It may be something bigger. I'm not sure, but when you're trying to figure out what the reinspection frequency is, you'd start there and grow from there. I would think that would be a way to do it. Makes sense.

MR. ALLEY: So we saw on Vendor A the blade probe performance, the open tube. Rotating probe performance, again, was a little better, 13 percent to 100 percent, again with the ideal orientation, and with the non-ideal orientation we had 15 to 100 percent.

You'll see these numbers pretty consistently through here, which tends to indicate to some we're probably pushing the boundaries of the technology.

Vendor B, we see the same numbers, 15 to 100 percent for blade probe and 15 to 100 percent for the non-optimum orientation blade probe. Open tube, we see down to ten percent here for this particular vendor, perform perhaps a little better, although we're starting to get, you know -- the five percent is starting to get kind of in the grass.

MR. ROSEN: What does the E in TWE stand for?

MR. ALLEY: The through wall extent.

MR. ROSEN: Extent.

MR. ALLEY: Then the open tube rotating probe, tube to weld interface. One vendor chose not to try to qualify detection. Vendor A chose not to try to qualify detection of flaws in the weld metal

with the tube scanner.

Vendor B selected to try to demonstrate that they had the ability to see through the tube into the weld metal. So we saw that we were able to see tube to weld metal interface flaws when the flaws extended up to the triple point. So that big, long flaw that we showed in that mock-up when you asked where the triple point was, you're able to detect that at the interface. The flaws that actually weren't that large and went through that interface you were unable to detect.

The weld metal is highly attenuative and very, very difficult to examine, and what we're finding out is even under the best of conditions right now to get sound energy through the tube and into the weld metal and get any kind of detection there is quite a challenge.

CO-CHAIRMAN FORD: I recognize, Tom, that you're not qualifying people, these vendors. If he chooses not to do it, then do you use him?

MR. ALLEY: Well, it depends on your philosophy again. I mean, some utilities said that I'm going to use as a basis for my inspection program an examination of the triple point to show that I have no leaking into the annulus and, therefore, no

circumferential flaw.

So if that utility used that as an approach, they would go to this demo, and I would think that they would have to have a vendor that would be able to interrogate that interface. If they didn't, then to me then they would have to take an alternate approach.

That kind of leaves some flexibility in the situation as I mentioned before.

Okay. Again, just to reiterate, the weld metal flaws that did not extend up to the triple point were not detected. So if we're seeing anything in that weld metal, we're seeing just a very, very small volume of that weld metal right at that tube interface.

Vendor C looked at blade probe UT as well, 16 percent to 100 percent, 18 to 100 percent. The open tube scanner was 13 to 100 and flaws ranged from 15 to 100 with the open tube scanner that are oriented parallel to the beam direction.

Again, we're seeing a lot of consistency in these numbers. They are from ten to 15 percent to 100 percent through wall for all of these vendors. Now, what that means to me personally is we're starting to push that technique about as far as we can

get it. It's very consistent from vendor to vendor, and they're using different transducers and different probes and things that are slightly different. It's each their own approach to solving this problem; yet they're getting the same performance from it. So I tend to think we're probably pushing the bounds slightly.

MR. POWERS: Does it also mean that the test is not very challenging to them?

MR. ALLEY: It's not very challenging?

MR. POWERS: Yeah.

MR. ALLEY: It's very challenging. It's very challenging.

MR. POWERS: If it was very challenging, wouldn't you see a scatter between the best and the worst and things like that?

MR. ALLEY: Well, when I say very challenging, I think that if you look at the open tube scanners, we're using the sheer wave data, time of flight data. We're using straight beam data. We've got about all of the sound energy in different modes that we can put into that volume we're putting in that volume with those open tube scanners, and these are the results that we're getting out.

And I think that's telling us that with

everything we know to throw into that volume, these are the best results we're going to get. And we're seeing that consistently from vendor to vendor.

I will say there's not a whole lot of difference in the way that they have attacked this problem with regards to their techniques, but then, again, those techniques are pretty readily understood by the industry as being the best techniques available to do this.

The next slide gives us just the flaw designations and nomenclature again. This will go along with the table I'll present in a minute. You have these in your handout, although they might be hard for you to read, but it gives you the orientation, the flaws, and the type of flaws that were contained in that mock-up. So this is just a key for the table I'm going to show you next.

This is just a representative sample of the results that were obtained. The reason I wanted to show this to you is not necessarily to communicate the exact results that we achieved with this vendor, but to show you all of the variations that we have and the inspection capabilities that were there.

You see the A, B, and C type flaws that were referenced in the previous slide. You see down

the left-hand side the axial blade probes, the circumferential blade probes, the open tube scanners, you see different increments in the open tube scanner. You know, we're looking at do we take five degree slides through these probes or three degree slides through these problems. It basically doubles the inspection time for the utility.

So if the utility wanted to take a farther B cut through it, what does that do to the detection limits and the ability of the system and the performance of the transducers to increase those increments?

So we tried all of these different variations. So this table here was just to basically highlight to you that it's a very complex set of results that are used when an individual utility would go in to select a vendor.

The next slide I wanted to talk briefly on the eddy current demonstrations. One vendor chose to demonstrate eddy current at the time of the 2002 demonstrations. We've got very, very mixed results with regards to eddy current.

As we've already alluded to earlier, detection is very sensitive to the weld surface conditions, and we'll give you some data that supports

that conclusion.

The ground surface condition, we had smooth surfaces of the welds to do the eddy current inspections on. We were able to detect 1/160,000 inch long flaws with about 3/10 of a mil in width.

To contrast that, on the unground, as welded surface conditions, we did detect a flaw that was a half inch long roughly by two mils wide. We also missed a 1.5 inch long flaw that was five mils wide. Okay? So we're very sensitive to surface condition with the eddy current.

And EPRI right now is working on increased sensitivity with array (phonetic) probes and some other probes that we're trying to deploy to help eliminate some of these issues, but what we're finding out with eddy current is that there's going to be aswamp between the false call rates and the detection limits of what we have and what we're able to find in reality.

We could go in and we could increase the sensitivities and increase the gains of these probes so that we found everything and just paint the surface black, but that doesn't help us decide what's real and what's not real.

So there's this constant swap in eddy

current in trying to find this middle ground here where you've got good sensitivity for the flaws you want to find, but you're not out there increasing your false call rates to a point that you can't manage the false calls. We've got some work to do in eddy current.

CO-CHAIRMAN FORD: Is there any, quote, control on the grinding that has to be done in order to make this be more sensitive?

MR. ALLEY: Well, there is no grinding that we do in the field because if we grind in the field, we induce cold work in the weld, and that's going to cause us a lot of problems with crack initiation. So we're stuck with what we were delivered during the original manufacture.

CO-CHAIRMAN FORD: Okay.

MR. ALLEY: So, you know, one of the challenges that goes to a utility if they want to do the eddy current examinations or to look at the surface conditions of their welds and make certain that that's a good exam philosophy for them to adopt, and if it's not, then they need to go to the volumetric exams of the two materials.

So, again, it's pretty much utility specific.

MR. MATHEWS: Correct me if I'm wrong. I believe that long flaw that was missed was on one of the rougher samples.

MR. ALLEY: It was a very rough sample. I mean, this is the extreme, but it does give you an idea.

Future demos. The Technatome folks are going to demo eddy current of the attachment welds. That's scheduled for next month. We've already completed the volumetric exams there, open tube and blade tube scanning capabilities for one of the vendors there.

Framatome is going to eddy current the attachment welds. We just completed kind of a preliminary scan last week with the Framatome scanners deploying the new EPRI array eddy current technique. They had some scanner problems, some contact problems. So they've gone back to work on that some more.

There's other surface methods that are being looked at by the various vendors out there. Framatome and WesDyne both are looking at a thermal imaging process where they induce a laser thermal field in the weld surface, and that's affected by the track, and you get a thermal image back.

So they're both working on the deployment

of that.

WesDyne is looking at the UT end of the tube to weld interface steel. Again, that's looking at the critical point. They're trying to increase sensitivity of that area, eddy current of the attachment weld and, as I mentioned before, thermal imaging.

B&W Canada has recently come onto the scene as far as inspection capabilities for pre-service inspection of new heads. We basically invoke the same requirements for pre-service inspection that we do for in-service inspection. So we're able to baseline what's out there.

One of the biggest issues we have to deal with right now in the inspection community is we don't have a baseline of what was originally manufactured. So that's a lot of the issues the utility has with doing eddy current today and doing penetrating exams today, is that we know the crack growth rates in the weld metal are difficult to manage. Yet we know that these weld metals contain point type defects and little defects in them that have been there since the day they were manufactured.

So we continue to wrestle with how we're going to handle that. Now, we're going to get ahead

of that on new heads, as I'll mention here in a minute, but B&W Canada is scheduled next week actually to start doing the UT examination of the mock-ups, and then in May they're looking at doing eddy current exams.

Future activities for the inspection committee. We have a new set of mock-ups under construction. We got a lot of feedback from the vendors that indicated that the mock-up process that we use now gave them a very good opportunity to train people. They go out in the field and they may not see a flaw for two or three exams, and we've got blocks in here that have got 30, 40, 50 flaws in it.

So we'd really like to have the key to these blocks so that we can train people on what we have. We thought that was a very noble cause.

We're going to manufacture another set of mock-ups that can be used as blind mock-ups, and we're going to turn over all of this data to the inspection vendors in hopes that they will be able to train people and improve their capabilities.

Replacement head inspections. We've issued -- is the letter issued now, the pre-service letter? We've got a letter either issued or pending to be issued recommending the pre-service requirements

for anybody having a head manufactured now, which will include surface weld, eddy current, PT, volumetric of the tube.

We're also going to do equivalent studies. We believe there will be no acoustic differences between Alloy 82 and 182 and the 52 and 152, but we're going to build a miniature set of blocks into acoustic studies on that so that we now feel very comfortable in using the demonstration process that we have demoed for the Alloy 600 on the new fabrication. So we're in the process of doing that work.

Now the mock-up drawings are already in place, and then as we have mentioned before, we're very much tuned to what's going on with the North Anna head. We've asked the inspected vendors to provide inspection data or rescan the tubes that are going to be destructively analyzed. I think it's vitally important that we're able to compare the truth to the indicated.

So in summary, the MRP has an organized and comprehensive approach to the recent industry events. We believe we've made considerable progress considering the short amount of time we've been working on this. We didn't have techniques for doing this two, two and a half years ago. I think we have

come a long ways with the demonstrations and the development of equipment.

The demonstrations are an ongoing process. I don't see it coming to an end any time soon. We're getting ready to go through another round as you saw on the future correction, and we don't see that coming to an end.

We realize that there needs to be increased emphasis on the attachment welds and inspection frequencies. We're working on a rate probe right now, eddy current, to do the J groove welds and improve inspection capabilities on that.

And that concludes the comments I have for you.

CO-CHAIRMAN FORD: Tom, thank you very much.

I believe, Alex, you would like to make a comment? A couple of minutes. The industry --

MR. POWERS: let me just ask one question. This was very interesting and nobel effort to develop and test the capabilities to detect cracks, but you're still doing it with artificial cracks, cracks not produced by chemistry, but you're going to apply it to looking at structures that, in fact, have root cracks, root cracks produced by chemistry.

When do we get a report card or how do we go about getting a report card that says, "Gee, these guys inspected all of these locations and they got 99.3 percent of all the cracks"?

MR. ALLEY: That's going to be very difficult because you'd have to cut up samples essentially to understand what you missed. I think it's pretty easy -- I won't say it's easy because it's difficult just from an access standpoint, but it is an easier question to prove that you saw what you saw. What's difficult to prove is that you didn't see something that's out there, and the only way to do that is just to take good samples and start cutting those up because we don't have a way to know that there's anything in them.

So that half of that question is doable, and I think the North Anna piece is certainly a component to that. The other half of that I just don't understand how you would do that. I don't understand how you would understand what you've missed.

The other that I think is an important comment to make with regards to real flaws versus fabricated flaws, and that is we continue where we have real flaws and where we have removed real flaws

from service and understand what they are. We continue to compare the ultrasonic signals, the wave forms that were generated from real flaws to those from manufactured flaws, and we have very good correlation of the signal responses of the manufactured flaws to the real flaws.

So we continue to try to get better and better information with regards to showing that the fabricated flaws have similar responses to the real flaws.

MR. POWERS: The difficulty is there doesn't seem to be -- I mean, I never see a plot that says, "Here is the realness of my fabricated flaw, the fraction of realness," you know, some measure of, you know, what a real flaw looks like versus a fabricated flaw. I've never seen anything like that. I never know. They say, "Well, it's a good characteristic," but you know, I'm a very generous person. I'll say that something is good that Peter here would say that's bloody awful or some equivalent expression.

MR. ALLEY: Well, again, what we have done is we have taken ultrasonic responses. I believe we took some off of V.C. Summer actually and did acoustic studies looking at the way forms and the way that that data was generated by and compared that to the

manufactured flaws to make sure that the way forms appeared the same.

We do those where we have the opportunity to do that. We have some data on that. I don't know how extensive it is, but we do have some.

MR. MATHEWS: And it seems like in the PDI process where they were coming up with how you build the lots of samples you've got to have for doing PDI. They went through extensive discussions with Dr. Doctor and others at the staff about what's an acceptable way to build the flaws to put into the samples to do your PDI testing, and so some of that was, you know, I'm sure used in the thought processes of the people who were designing these flaws.

MR. ALLEY: And, again, for the qualification and demonstration process you have to know the dimensions of that flaw to be able to answer your other questions that you have about how accurate are the results. So you've got to weigh the accuracy of the information that you're treating as truth.

MS. WESTON: Tom, are the heads that have been replaced, candidates for looking at actual flaws of those you might have missed?

MR. ALLEY: Certainly North Anna is. That's one of the things we want to do with with North

Anna. I don't know that there's any work proposed right now on any of the other heads to do anything like that.

Certainly the Duke head, I know, we fixed all of the flaws we found. We ground them out. They're on chips on the floor. So I don't know what opportunities we'd have.

The North Anna head certainly presents us with a great opportunity, and we're going to seize that.

MR. MATHEWS: And the nice thing about North Anna -- well, I won't call it nice. The North Anna 2 head was replaced in an outage in which there was a lot of inspection done, and then the decision made to replace. Most of the time when you're replacing the head, you've planned it.

We're not going in and spend two or $3 million to inspect something that's going to the garbage dump, and so you don't have that last cycle inspection result unless you go pay to do it.

CO-CHAIRMAN FORD: Are there any other questions for either Tom or Larry?

(No response.)

CO-CHAIRMAN FORD: Okay. Alex.

Thank you very much.

MR. MARION: Thank you.

For the record, my name is Alex Marion. I'm Director of Engineering at NEI.

And during the discussions this morning, I realized that it may be informative and useful to you folk to get a sense of what we have in place within the industry to take a more holistic view, an integrated view of how industry deals with the management of materials issues moving forward.

And let me just make it very clear that when the EPRI materials reliability program was formed, the basic objective was to position it to be totally proactive, and as you heard this morning, looking at the regulatory documents that have been issued over the past couple of years, specifically three bulletins and an order, it's very difficult for a group like the MRP to be proactive in that kind of environment.

Now, here we are today with new findings coming out of the South Texas project, and we have to wait and see what the results of the analyses are and then determine what the generic applicability is going to be, et cetera. And, again, we're in a reactive mode in dealing with the planned experiences.

Last summer as a result of the Davis-Besse

event, questions were raised among the industry chief executive officers sa to whether or not the industry was dealing with these issues with the proper perspective. Are we looking at them as completely as possible, as objectively as possible so that we can determine what needs to be done and then apply the industry resources to do that, and can we position ourselves to deal both with the reactive element of these issues, as well as the necessary proactive element?

And from those discussions an executive task force was formed and a working group, and the initial thrust of the effort was to conduct a self-assessment of the industry programs, of the major industry programs dealing with materials performance issues.

And the self-assessment was completed. Findings and recommendations were communicated to the industry chief nuclear officers, and we've developed a guideline document for a more balanced and a more integrated, industry-wide management scheme for materials issues moving forward.

And that document was just distributed to the chief nuclear officers last Friday for their review and approval, and we hope to get their support

to endorse a formal industry initiative that establishes this new management process in an integrated manner as the industry moves fowards in dealing with materials issues in the future.

This is not in any way a criticism of any of the programs, and it does not in any way suggest that the existing programs have to change drastically, but what we're trying to accomplish with this effort is to position the industry overall to be more proactive when -- let me give you an example -- when an issue occurs at a plant.

The first question that comes to mind: what do we know about this degradation mechanism? What do we not know? What do we need to do to improvement our intelligence base so that we can move forward with the right course of action in terms of inspection and repair mitigation, what have you?

And as you can appreciate, some of these are very complex, technical issues. As we talked about today, a lot of information needs to be brought to bear if you're going to make the right decision.

So clearly operating experience and improving your knowledge base on this degradation or these degradation mechanisms is very important, and we're hopeful that we can position the industry and

deal with a lot of this information on an international level to make our actions in the future much, much more completely informed.

Our goal is to be sufficiently proactive so that we can prevent events at plants or incidents at plants, as Chairman Diaz likes to characterize Davis-Besse, at a minimum, and that's what we hope to achieve. And I thought it would be of some interest to you to get a brief discussion of that.

And that completes what I had to say. I don't know if you'll have any questions about the effort or not. Our intent is to have this new process in place effective the first of 2004.

CO-CHAIRMAN FORD: Thank you very much, indeed.

MR. MARION: Thank you.

CO-CHAIRMAN FORD: Any questions?

(No response.)

CO-CHAIRMAN FORD: I'd like to thank the industry presentations, representatives. Thank you very much, indeed.

We're going to change now to the NRC and Bill Cullen.

MR. CULLEN: All right. Let's go here because we've got the TV and we've got the handouts

and we've got everything else.

For the record, I'm Bill Cullen from Materials Engineering Branch here at the U.S. NRC's Office of Research.

Just a quick word. I joined this agency just a hair over a year or so ago, and within about 30 days after I started we got notification about Davis-Besse.

MR. POWERS: Oh, so you were the responsible party here.

MR. CULLEN: Something like that must have happened.

So this is my first presentation in this go-round in front of the ACRS, but about 25 or so years ago when I was a contractor to the NRC, I had a few opportunity to appear before the then ACRS.

I've got several things we're going to talk about today, but they do all fall into the very general categories of CRDM cracking issues, which of course we've been talking about virtually the whole morning.

And then in the second almost half of the presentation I want to talk a little bit about some of the specifics on Davis-Besse and what the Office of Research is doing to address some of the issues raised

by that.

So moving ahead here, there's a half a dozen or so individual items. We're going to talk a little bit about the research that we're currently funding in those areas that are shown; a little bit more on some additional programs that are not funded by the NRC, although we may participate in some of these efforts, but these are efforts in other countries and by other groups that really do bring an awful lot to bear on the topics that we're talking about here.

I want to talk a little bit to get a little more into some specifics about some things that I feel could be done or could be certainly thought about to be done here in the U.S. to look at some heat-by-heat analyses of the tubing materials that are in some of our plants; look a little bit at a topic that has been mentioned and, in fact, somewhat extensively this morning, but no mention of this topic could be extensive enough for my liking. I think that stress analysis of these penetrations offers an awful lot of potential for our understanding of what it is that is going on in these things.

I'm going to talk a little bit about the potential for NRC-industry collaboration, a potential

that -- and I'll be very honest about this -- is not approaching activation nearly fast enough to satisfy me, and I'm going to try to make a point of that when we get to it.

And then I'll close with a fairly extensive discussion on some of the findings that the industry has provided to us on their examinations of the Davis-Besse cavity and specifically what that means to the NRC and to the Materials Engineering Branch as research, in particular.

Also, just as a little bit of an advertisement, I'm going to talk up here about some LLTF, lessons learned task force, issues that they raised about stress corrosion cracking in the Alloy 600 and then the boric acid corrosion issue. But down here -- and you'll hear about both of these things in a much more detail tomorrow. One of my colleagues, Danny Santos will be talking specifically tomorrow about the LLTF recommendations on the barrier integrity or on leakage, and that's another issue that was raised somewhat extensively this morning and I think will be a good deal talked about tomorrow on the leakage issue and what those recommendations mean and what we might be led to in that particular area.

Okay.

MR. POWERS: Let me -- I mean, you've given me quite a list of research activities that you're involved in either as a principal or as a partner and a few research activities that you'd like to be involved in.

And what I'm struggling with here a little bit is why are you involved at all. I Mean, isn't this an industry problem? They've got to fix it. All the NRC has to do is say prove to me that your vessel has sufficient integrity for me to let you keep running.

MR. CULLEN: It sounds to me like a question you have asked before.

MR. POWERS: I'm practiced at this question.

MR. CULLEN: You've practiced this question. We've practiced our answer.

There are two reasons. One is that we must do an ASP, an accident sequence precursor analysis. IT's a congressional requirement, and for that ASP analysis, we have got to do calculations of the properties, the situation, if you will, at the Davis-Besse plant, starting from one year before this was found up until the time that it was found.

In order to do that sort of calculation,

there's a lot of information that we need about the shape and the size and the characteristics of the cavity and of the exposed clad. That's why I, in particular, as a materials kind of guy, am very, very interested in the findings that the industry has produced in showing what those findings are and what they mean to us.

It is not my position, however, to present these findings to you, to discuss them. You are absolutely correct in that regard. It's an industry problem, what it was that they found there and what it was that led to that. It's their responsibility to create the root cause.

The second reason that we're involved in this thing is that it is of enormous interest to a great percentage, great fraction of our stakeholders, internally and externally, the licensees, the general public, and for that reason we are doing a reasonable amount of research that addresses some of those specific things in which we have an interest.

MR. POWERS: It seems to me that what your stakeholders want could be adequately served if you worked as a clearinghouse and reviewer of information generated by the industry. I'll give in to you on Item A(2). You need some information, but the rest of

it, I mean, it seems like all you have to do is read Corrosion and Corrosion Science and keep --

MR. CULLEN: Were that the case. Well, a couple of ways of responding to that. One is on this issue of corrosion -- and, again, there will be another opportunity a little deeper into the presentation to get into this a little bit more -- I was quite aghast, is a reasonably good word, in the middle to later part of March when I went into the research to try to dig out some of the properties of corrosion of low alloy steel and boric acid solutions, and while there is quite a lot that has been written, EPRI had put together the "Boric Acid Corrosion Guide Book," with which you are familiar, and there's a lot of experiments that are discussed in there. Virtually none of them model accurately the Davis-Besse experience.

Now, you've heard this morning -- and it's correct -- EPRI has an RFP out on the market now to create some mock-ups, among other things, that would perhaps do that somewhat after the fact and will add to our research base, and we in the Materials Engineering Branch also have a corrosion -- work as a corrosion program that I certainly want to admit, if you will, that it was spurred on by the Davis-Besse

experience, but our program is not Davis-Besse specific in any sense of the word. It is more generically more broad based, broad brushed look at corrosion of low alloy steels.

MR. POWERS: I don't think the Chairman wants to spend an enormous amount of time on my little heartache here, but what I will comment is that when I look at this slide I cannot understand where you're trying to go with this corrosion program, what you're trying to achieve, what capabilities you want to have. Okay?

It looks like a bunch of things that you're plucking up to respond for the current incident, which it's worth responding to the current incident, I suspect, but I'm more concerned about the next 25 years where I'm visibly looking at things that have license removal and stuff like that.

MR. CULLEN: Well, I would agree with you that it is not in our mandate at all to address licensee specific issues and solve that issue for the licensee. We all understand that quite well.

But when some of these issues either cause us to recognize that there's a more generic substrate that underlies that, then I think that it is our business to go about investigating that generic

substrate, and there are some other things that bear on this, too.

I tend to think that we do have some mandate to resolve issues that are of concern to a reasonable fraction of our stakeholders, and I think this is certainly one of those things.

Okay. Let's move on a little bit here, and I do want to discuss one of these issues that maybe falls into this category. We are doing a structural integrity assessment of the cavity and the exposed clad at the Davis-Besse plant. That information is very specifically absolutely required by the ASP analysis, and it is for that that we are doing this predominantly.

MR. POWERS: Where do I go to find some documentation that says what's required and how well it's required to understand it?

MR. CULLEN: What's required? Are you asking for the statement of work that was generated for that program?

MR. POWERS: Maybe that's the document.

MR. CULLEN: That's the first thing that comes to my mind, and certainly tha t--

MR. POWERS: Somewhere somebody has said to do this ASP I've got to have this information, and

it has to be this good.

MR. CULLEN: Well, asking the question that way I'm not quite the right person to answer it, and I don't see anybody from the group doing the ASP that would be qualified, but I suspect they also have a statement of work that is required. Pat Bernowski's group and Gary DeMoss specifically is crunching the numbers and gathering the data.

We have, you know, a fraction of the input to that that I will describe somewhat briefly somewhat deep into my presentation here, and then as I've said now, I'm going to show some of the results that the licensees has provided to us about what they found in that cavity and what it really means, and then some other things that are spinoffs of all of this and why we are doing those things as well.

Okay. Expanding a little bit now on one of these items from the second slide, we have had for a great many years an environmentally assisted cracking program going on at Argonne National Laboratory, and this involves some tasks that are very specific to what we're talking about today: stress corrosion crack growth rate testing of nickel based super alloys both in BWR and PWR water because many of these alloys are used in both types of reactors,

although we're here today to talk about the cracking in the PWR much more.

We are doing more than just looking at stress corrosion crack growth rates. In most cases we're also taking a look at some of the other properties of these alloys that can be brought to bear, may have meaning for understanding the mechanisms of the stress corrosion crack growth process.

This program has been ongoing; this task in this program has been ongoing since about 1997; has generated a couple of NUREGs, which are certainly available, and we've been talking today a lot about stress corrosion crack growth rate in Alloy 182, and what I can point out is that we are due to receive a report on stress corrosion crack growth rates out of this Argonne program about a year and a half or so from now.

And then after much more testing has been completed, we're going to get another NUREG with the schedule in late 2005.

I can see a question coming.

MR. POWERS: I'm going to ask another question I'm practiced at.

MR. CULLEN: Go for it.

MR. POWERS: But I never get an answer to this one. Maybe I'll get one now.

We have 600 we don't like because of cracks. Now we have 690 that we like better because at least it's slower to crack. But my European friends, they're just ape over 800. Why aren't we excited about 800?

MR. CULLEN: I don't know the answer to that. I'd be happy to try to find that out. I'm aware that in the German plants particularly in some of the Belgium plants they --

MR. POWERS: They got religion over this subject.

MR. CULLEN: Now, they are using that in steam generators. I am not aware of its use in larger diameter, thicker section penetrations, but I'm guessing a little bit on that answer.

Does anybody have any idea? Keith?

PARTICIPANT: Germans' use of steam generators.

MR. CULLEN: Yeah. Let me paraphrase Keith's answer, which was the same as the one I gave. We know it's being used extensively in steam generator tubing and retubing, but again, I'm not aware of any use of that allow in thicker sections. It's pretty

expensive stuff, and that may be a reason that --

MR. POWERS: How expensive is it relative to pulling out a steam generator and putting it back in?

MR. CULLEN: It certainly --

MR. POWERS: I mean, it seems to me you can spend an awful lot on an alloy if you don't have to change your steam generator out every 20 years.

MR. CULLEN: Yeah, that's just not something that I can comment on at all.

MR. POWERS: I was just curious.

CO-CHAIRMAN FORD: I've got a question. When you say evaluating strength, is that specifically for this question about low temperature embrittlement?

MR. CULLEN: Not at this point. What I was referring to there is that as you know, Peter, there's some dependance or proposed dependance of crack growth rates on yield strength, of grain boundary carbide coverage, things like that.

Let me jump ahead to something I was going to say because I know this is very high on your mind. Can I give a little bit of a preamble though?

I'm not sure that everybody in the room understands what you mean by the low temperature degradation, but about a year or so ago, in the

summertime of last year, there was a couple of publications generated by what's now called Bechtel-Bettis Atomic Power Lab, where they presented some results of a low temperature degradation in fracture toughness, in fracture toughness of Alloy 82 and some of its near neighbor variations.

That degradation happened under some rather specific set of circumstances. It was at 130 degrees Fahrenheit that the degradation maximized. It was also maximized in very highly hydrogenated water. Normal hydrogenation would be around 30 to 50 cc's per kilogram of hydrogen. This degradation really kicked in at higher hydrogen concentrations. If memory serves right they were up in around 150 or so cc's per kilogram when it got to be really strong.

So this was a degradation in fracture toughness in Alloy 82 and some of its kin.

There also is a rather well know ductility dip cracking issue, which is a weldability issue. Okay. First off I was talking about a hydrogen assisted cracking issue. Now I'm talking about a weldability issue, also in this same alloy, and that data largely comes out of what we know is Lockheed-Knowles (phonetic) Atomic Power Lab. So it's basically the nuclear Navy people that have generated

the bulk of the work to establish the problems with Alloy 52, 152, and similar materials.

Some of these same problems are also found, by the way, in 182 and also in 690. I think that's important to remember, but the problem with stress corrosion cracking tends to disappear as the temperature increases.

So at reactor operating temperatures, this is a nonexistent problem. So there's two things going against this problem under normal operation. One is the temperature is too high. The other is that the hydrogen is too low. So we're not likely to get this degradation or I certainly wouldn't think we would get this degradation under normal operating circumstances, but this may be an issue of where there's smoke there's fire.

My position, and I'll speak really for myself, is that we want to stand back a little bit, continue to watch the work that is generated by the nuclear Navy, watch the work which is generated by the industry and make our own decisions about whether or not this really appears to be an issue that may have safety importance.

The other thing that we're going to be finding out starting quite soon is that the first of

the French plants to replace their heads is coming up for their ten-year inspection rather shortly, later this year, next year. I'm not sure, but very soon is the answer.

We're going to get the first evaluation, if you will, the first information about the performance of these replacement heads from the experience that the French will have in these inspections, and of course, you know they've been replacing heads at the rate of three, four, five a year. So they're going to be generating an equal number of ten-year inspections from now over the next ten years.

So we will be getting an awful lot of information, precursing information that should be very, very useful to us. Again, I have a few more things I want to say regarding that, but it all bears on what I think we will be able to find out going forward on this issue of Alloy 52 and 152.

So going back to Peter's question, to try to bring closure to that now, Peter asked me whether or not we're evaluating strength in the sense of the low temperature degradation and toughness, and the answer here is no. We are evaluating strength within our program simply as correlative information to the

stress corrosion cracking determination on these particular materials.

CO-CHAIRMAN FORD: I don't doubt. I agree with you entirely. You're not going to get it at operating temperatures. My concern is more accident conditions. We might have a --

MR. CULLEN: Starts, shutdowns, standbys.

CO-CHAIRMAN FORD: Well, also thermal shock situation during an accident.

MR. POWERS: But if it's hydrogen embrittlement -- is that what I understand it to be?

MR. CULLEN: I would not use the word "embrittlement."

CO-CHAIRMAN FORD: I don't know if it's hydrogen embrittlement in the classical mechanistic sense. It is associated, as Bill rightly says. You've had hydrogen absorbed into the material. When you have the high chromium content, energy changes and, therefore, your plasticity changes, and it's a known fact as Bill says.

MR. POWERS: But it seems to me that certain events -- the hydrogen can't organize itself to do whatever it is that it does in the face of sudden events like pressurized thermal shock and stuff like that. I mean, it gets up to high temperatures.

The hydrogen is either desorbed or it has diffused kind uniform (phonetic). It's no longer creating anything that's vulnerable. You suddenly cool it. That hydrogen can't move fast enough --

MR. CULLEN: That's correct.

MR. POWERS: -- to respond. So it couldn't affect a pressurized thermal shock event.

CO-CHAIRMAN FORD: Maybe I'm using the wrong word, pressurized thermal shock, because maybe you're getting something in your mind about mechanism of pressurized thermal shock. I'm talking about a thermal shock on, for instance, the stub tubes into the top head, and if you had a burst of cold water, regardless of how you got it, could you get a thermal shock on a pre-cracked stub tube sheer-off?

That's purely my scenario. I think it's rather low possibility, but it's interesting.

MR. CULLEN: But I think it's our job to try and think about these sorts of --

CO-CHAIRMAN FORD: The worst case scenario.

MR. CULLEN: The right temperature, the right stress, and the right hydrogen content, and then we could have a bad problem.

CO-CHAIRMAN FORD: The other question I

wanted to ask you about that first line and then we'll get off it is PWRs. I understand why you're working on BWRs. Is there anyone in research or in NRR looking at the question of cracking of BWR bottom head penetrations?

MR. CULLEN: I would say not looking at, so far as I know.

CO-CHAIRMAN FORD: Evaluating?

MR. CULLEN: Yeah, we're aware of the one issue -- I think it's only one -- in Japan to this point. That was a rather small flaw. They found it; they disposed of it.

I know from a research point of view, we are not doing any specific research other than trying to maintain an awareness.

CO-CHAIRMAN FORD: I'm sort of inviting Al to say something.

MR. HISER: Oh, boy. We'll talk about that tomorrow.

CO-CHAIRMAN FORD: Fantastic.

MR. HISER: How does that sound?

MR. CULLEN: Okay. Items B and C I put on here because I want to create a lead-in to a great deal more discussion I want to have a little bit later on. We are doing some testing of materials removed

from Davis-Besse, both the Alloy 600 from nozzle number three, which is the heat that appears to crack the most predominantly and Alloy 182 from the near neighbor nozzle J weld.

We're doing this sort of testing simply to create data on what may be susceptible materials and add that to the overall database of Alloy 600 and Alloy 182 stress corrosion crack growth rate.

The LLTF made a number of recommendations. A great many of them fall into the stress corrosion crack area. One of their recommendations was to create or write a critique of the susceptibility model. This also came down to us as a user request from NRR. I've completed this report a couple of months ago. It has been circulating internally, been revised, and will be available much more generally within about three or four weeks. And certainly I can see that it will get sent down to you.

I'm going to talk about this a great deal more four or five slides down the road because I want to mention some of the things, some of the issues, some of the additions, improvements that might be possibly made to the time at temperature susceptibility model that was talked about a good deal this morning.

There are two other deliverables that are both coming forward from here. One is to write a report, collect the worldwide Alloy 600 cracking experience and produce that report late at the end of this year and another to collect the boric acid corrosion experience worldwide and produce that report later on in 2004.

CO-CHAIRMAN FORD: Just to make sure we're talking about the same thing, the report talked about on C-1 is the Rev. 1 of MRP 75?

MR. CULLEN: No, no. This is absolutely independent. Do you mean the susceptibility report?

CO-CHAIRMAN FORD: Yes, your C-1.

MR. CULLEN: No, that had nothing to do with MRP 75. That was something generated entirely within the MEB.

CO-CHAIRMAN FORD: No, but it's the model that was used.

MR. CULLEN: Oh, it's the model that was used, yeah. I'm sorry. Yes, yes. Yeah, I'll show the usual chart that you expect to see in a few minutes.

CO-CHAIRMAN FORD: Okay.

MR. CULLEN: Okay? And talk about some of the things that I think could be done to fix that up.

Okay. There are a number of additional programs that, as I said in my prologue, we're aware of; we're participating in to some degree or other. We are not funding any of these things.

I think it's important for everyone who's interested to know a little bit about these things. The Japanese are doing an awful lot of crack growth rate research on the alloys in which we have an interest.

As you might expect perhaps, it's a little bit difficult sometimes to find out about this data. I'm going to make somewhat of an effort using the appropriate international channels that we have here available to us at the NRC.

MR. POWERS: Just ask our subcommittee chairman. He spends half of his time in Asia.

MR. CULLEN: Ah-ha, there we go. But there's a lot of data that the Japanese are generating that would be very, very helpful. Some of the data from this electric joint research project which is now completed actually is beginning to show up in the literature.

In fact, we'll talk about the postpones conference that I was going to have towards the end of March. There was going to be one paper in there with

some of the results from Alloy 182.

There is a much larger program, the national nickel based alloy material project which continues through 2006. It's a multi, multimillion dollar funded program, almost exclusively directed at stress corrosion crack growth rates, and at this particular point I have no knowledge, cannot find any knowledge at all on when we would expect to get any results out of that at all. I'd like to find that out somehow.

Another thing that's going to provide a lot of data is the International Cooperative Group on Environmentally Assisted Cracking, ICGEAC, which is in the beginning stages of conducting a round robin on Alloy 600 crack growth rate testing.

At the present time the specimens for testing have been distributed. Some tests have been completed, and we will begin to get the first of the data next month.

MR. POWERS: And you say we're not participating in this one?

MR. CULLEN: We are members of the ICGEAC, both the NRC -- I mean, I attend those meetings. Argonne Laboratory people attend those meetings. There is 100 or so people that attend those meetings

worldwide. So we participate in the meetings.

Argonne is actually participating in the round robin, and they will use NRC RES funding to pay for the testing.

MR. POWERS: Okay. So we're -- that's good.

MR. CULLEN: Yeah, we're an active participant on the same plane with everybody else.

MR. POWERS: That's good.

MR. CULLEN: Okay. The Phase 1 of the test was just to collect data on how people did the testing and shake down a test routine that everybody could use.

Phase 2, which is the one that we're in right now is to test a 30 percent cold-worked Alloy 600, then compare those results and prove the methods and do a follow-on test. Thirty percent cold-worked Alloy 600 should crack fairly expeditiously, shall we say? The test should last about a month or so, given what the specific test parameters are. It should not be an impossible onus on any laboratory.

In Phase 3, we will go on and test Alloy 182. So we will get a good deal of data on both Alloy 600 and Alloy 182 out of this particular round robin experience.

MR. POWERS: And what do we do with that data?

MR. CULLEN: We will throw it up on that curve, that data plot that you saw earlier this afternoon and I'm going to show next, and I'll talk about that, again, in just a couple more minutes.

Just very quickly and qualitatively, there's also testing underway in France, Spain, Sweden, and perhaps in other places that I have not heard about. These are individual labs or individual agencies that are doing their own test programs, and again, we would expect that over the long haul that data also ought to be made available.

We're currently in a dialogue to obtain some of the mock-ups from replacement head fabrications. Specifically we're working with Duke Energy to get a mock-up that was created just prior to the Oconee 3 head being fabricated.

We will use that mock-up as a test bed for residual stress determination, for obtaining materials on which to do testing. Of course, those materials would be Alloy 690 and Alloy 52-152. I'm not exactly sure what the weld materials were that went into that head.

Okay. I'd like to take two slides and

digress a little bit about what knowledge might be gained from some of these heads that we're discarding for one reason or another. As an example to start with here, if we look at the head that came off the Davis-Besse plant, there are three alloys in there, in that head, that are also used in other plants.

Now, as it turns out those other plants are Oconee 3, Ark. Nuke. 1, Oconee 1, and -- oh, I'm sorry. This one here is a heated material that is actually not found, but it's a heated material that may have some sensitivity or susceptibility to stress corrosion cracking.

Now, these plants over here in which these materials are found are all having their heads replaced. So there's no particular need to learn something specific about stress corrosion crack growth rates in these particular heats of Alloy 600 in order to apply that information to these heads. That's a nonstarter.

So the conclusion here is that specifics about those particular nozzle heats from Davis-Besse are not applicable in the long term.

However, that's not the situation with the North Anna 2 head. We saw over here a listing of all of the heats of Alloy 600 that were found in North

Anna 2 and where those heats show up in some of these other plants.

Now, as we just learned this morning, North Anna 1 is also replacing its head, as is Surry 2, but these other plants, Sequoia 1 and 2, Watts Bar, Catawba, McGuire, don't have any immediate plans. I think Sequoia has got a long term, maybe 2006 plan.

But what the implication here is is that if some licensee would like to have specific crack growth rate data in order to use in some sort of a disposition presumably of a flaw that they have found, they know where to go and get that information.

So there's a great deal to be learned, to be obtained potentially at least from some of these heads that are coming off, and I think it serves everybody well to kind of keep a little matrix, as the MRP is doing, by the way. All of this information came from documents that were provided to me by the MRP, and I just want to point out that this potential for learning, very helpful information does exist.

CO-CHAIRMAN FORD: Bill, we often ask the question can you identify the heat in a specific head penetration, and you get mixed answers. You're saying you can. But every particular tube penetration --

MR. CULLEN: Okay. I've got to stop short

of saying we can. I've heard also the same anecdotal information that you have, that the individual licensees probably have this information. Certainly in the case of the BMW plants we know for a fact that the pin by pin information does exist, has been documented.

For some of the other vendors, I have not had a qualified vendor representative look me in the eye and say, "Yes, we know exactly what is in penetration number such-and-such at plant so-and-so."

But I would tend to think that that information is available. Now, we may have a problem with a few heads that were fabricated by vendors that are now out of business, but other than that, I would tend to think that the information is available and that is what I have heard.

Okay. Just a quick word. I think most of you were aware that we were supposed to have a conference March 24th through the 26th, but due to the geopolitical situation, to use a politically correct term, that conference was canceled when we found out that several representatives from foreign countries that we really needed to have attend in order to have a complete picture about what the worldwide situation was were not going to be permitted to travel to the

United States during that particular time period.

We again polled these people last week, and there are still a handful who are not permitted to travel even within Europe at this particular point. We're going to continue to keep polling the people who said they're going to attend and others as well, and when the restrictions have been lifted, when the coast seems a little more clear, we'll get about rescheduling this conference so that we can bring together all of the people who have good information on the inspection, on crack growth rates, on repair issues, on plant operation issues, get them all into one room for three or four days, and have a real good meeting to try and come up with a good evaluation of where we are and where we are going, in particular.

Okay. I've got three or four slides I want to present here that talk a little bit about the NRC sponsored work on stress analysis, and I said again in my prologue that I really feel like this is very, very important work. As far as I know, this sort of work is being carried out by a mere handful of vendors here in the United States. I can only think of three: Structural Integrity Associates and Dominion Engineering, both of them doing work for the licensees, and EMCC, which is doing work under

contract to the Materials Engineering Branch. Of course, this is the EMCC results that I'm going to show to you.

Fortunately from what I have seen, all three vendors are generating results which are more or less the same. That in a sense may be good news, but I do lose a little bit of sleep wondering whether all three of us are wrong.

The question was raised this morning how is it that you calibrate this stuff. Has this stuff ever been calibrated?

I felt the answer was only partial. There was some mention, Al Hiser mentioned correctly, and I mentioned that there had been some experimental verification of these computation algorithms done by Electricite de France in the early 1990s, but most of that work, in fact, I think, even all of it was done on pressurizer nozzle designs.

The residual stresses were measured using the X-ray techniques, which is quite a reasonably good method, gets only the elastic part of the strain, not the plastic part, but it's a reasonably good way to evaluate residual stresses, and the agreement was at least in the publications I have read stated to be rather good.

I am not aware -- and if somebody does know, I'd appreciate hearing that information -- I am not aware of any extensive, well qualified, calibrated work, if you will, on a full scale CRDM nozzle, which would be typical of a power reactor head. That is something that I personally would like to do. We've got the heads coming off that allow us the potential to do that kind of thing. We're also exploring the possibilities of doing that kind of thing in some mock-ups.

And I am aware that the industry is also at least thinking about that. David, do yo u know where you are in your thinking? Is it more positive than just thinking at this point?

MR. STEININGER: I remember talking to Al McElry about whether he was going to put something like that in the RFP, and he indicated at that time that he was.

MR. CULLEN: Okay, all right. So --

MR. POWERS: This is one of those things that you do once or is it something that you have to do all the time? I mean, is it a one shot deal or is it answers all of your questions or does it have to be --

MR. CULLEN: I think the answer from an

idealistic standpoint, the answer is you do it once and you're done.

However, there are so doggone many variables that you will be doing an almost infinite number of cases once, and what I'm thinking, what I'm alluding to is not only the fact that you have the geometry problems or the geometry issues. What's showing up here just as an example is the number one nozzle, the absolute center nozzle. That's the only axi-symmetric position in the whole head.

You've got all of these nozzles that are on the side-hill. Each one of them has -- well, not each one of them. There obviously are some multiples, but a great many of them, maybe eight to ten combinations, all at different inclinations.

Then you've got the potential issue of how these things were actually assembled. During the course of the assembly, how many weld beads were ground out and laid back down a second time or a third time or whatever?

Then you have the issues of repairs. There's a lot of issues which I think you could or a lot of considerations that you could basically sum up by saying geometry differences that you really need to have a look at in order to get the whole big picture.

We may get to a case or to a situation, a time frame with the ever increasing computational speed that we have available to us where this might not be such a big deal no matter what the differences might be for a nozzle that you'd like to know about in particular. You could devise the input necessary for that, run that into your computer, go home for the night and come back the next morning and you've got the answer.

Right now, this whole business, which I'd like to describe briefly at this juncture, all three of the vendors that I've mentioned earlier proceed in roughly the same way. Using finite element techniques, you cast a weld bead, a single weld bead. You allow it to cool, contract, build up the strain. You do that calculation. Then you put down the second weld bead, allow it to cool, contract, and put down its strain, and so on and so on.

You build up this weld bead in the way that is shown in this figure provided by AMCC, and at the end you then have a couple more steps that you have to do.

This entire thing is then -- again, numerically you simulate the hydro test, the 1.25 hydro test that is applied pre-operation, and that

gives you then the final stress state that obtains in that particular nozzle weld.

MR. POWERS: If the finite elements are no more dense than what's shown on your figure, this is a few minutes on a good machine.

MR. CULLEN: This whole process of casting these in bead by bead, allowing the cooling, the contracting for which you need stress-strain properties for the whole temperature curve, thermal conductivities for the whole temperature curve -- it's a good thing you're sitting down -- takes about a month on a two megahertz personal computer.

MR. POWERS: Oh.

MR. CULLEN: Okay?

MR. POWERS: On a PC.

MR. CULLEN: Well, yeah.

MR. POWERS: Oh.

MR. CULLEN: That's what's available to us. we don't have Crays underneath our desk unfortunately, or whatever.

MR. POWERS: A few more Crays. I've been marketing machines lately.

MR. CULLEN: But you get the drift of what I mean.

So that's where we are with these

calculations these days.

A couple of examples. An example of the axial stresses. Now, red is bad; blue is good. Red is tension; blue is compression. And you can see that as far as axial stresses -- now, axial stress in this direction causes circumferential or would drive circumferential cracking -- is maximized here right at the toe of the weld on the outside diameter, which by itself would not be a particularly problematic area.

What would be a little more problematic is that you've got another elevation in stress right up here which is above or at the triple point of the weld, and if you get a crack growing up in here, emanating from that particular elevation in stress, admittedly it's not so high as down here at the toe, bt it is in positive territory. That's the one that could drive a circumferential crack.

But that's not the whole story. There's more than just axial stresses in there. There's also hoop stresses, and hoop stresses would tend to drive the axial cracks, and as you know, we've got as we heard this morning at least by current count slightly more axials than we do circumferentials. So the size of the high tensile area is quite a bit larger, extends essentially throughout the entire volume of

the weld, with the exception of this toe back here near the clad, and well up into the Alloy 600.

So that's why at least in the center position we can understand why we're getting a good many axial cracks.

The last slide in this series is that if you compute both the axial, the circumferential, and the radial stresses, it turns out that the resolution of these stresses is on an inclined plane. I'm kind of waving the laser here in parallel with the arrows, which I presume are visible to you more in front of the screen. But what this says since a crack tends to grow normal to the principle stresses is that cracks should grow perhaps somewhat along -- these would be a circumferential crack now -- perhaps along about a 45 degree incline plane.

I'm not talking here about the fact that in a side-hill nozzle that the cracks are growing in a kind of oval, which is on an inclined plane. I'm talking about through thickness they're also on an inclined plane.

Remember this particular modeling is for the center hole position, which is the axi-symmetric. You know, there's no side-hill in this particular case, but we don't know whether this is the case or

not because all of the cracks that have been found to date have been ground out and repaired.

However, with some of the heads now coming off, we again have the potential to find out whether or not these stress calculations are predicting correctly the inclination of the cracks.

MR. ROSEN: Bill, these are great pictures, but I don't think you'd be showing them to us unless you thought stress mattered, and what we've heard over and over again is just tell me how long the stuff has been at a given temperature, and I'll tell you what the problem is or if there's a problem.

And now what I think I hear you saying or getting ready to say is stress matters.

MR. CULLEN: Yeah. I really believe that. I saw the slide this morning that stress is a secondary consideration. Crack growth rates are the primary consideration. I don't disagree with that conclusion at all. But --

MR. ROSEN: Crack growth rates are the primary -- you mean --

MR. CULLEN: Well, crack growth rates are temperature dependent.

MR. ROSEN: Yeah, temperature.

MR. CULLEN: You know, through the

temperature dependence of the crack growth rates. I thought that -- correct me if I'm wrong. I can't remember whether it was Larry or David that had that slide, but I think the inference at least -- do I have it right? -- was that the stress was secondary to the crack growth rates or did you say stress was secondary to temperature?

MR. MATHEWS: It was a secondary impact on the core damage frequency relative to the --

MR. CULLEN: All right. Well, so we're more than once removed.

The message wants to be here that crack growth rates are temperature dependent. They are the most important consideration in the calculation, if you will, of susceptibility of an individual plant.

But I'm here to say that I think stress is important. The message I'd like to deliver is that after all, we call this stuff stress corrosion cracking. If we didn't have stress to start with, we wouldn't be here, folks. If these guys 30 years ago understood all of the ramifications of residual stress and also figured out some way to get rid of all or most of it, we wouldn't be here today.

MR. ROSEN: Well, I'm going to say that up until now I've been thinking that all I know is the

effect of degradation years, and I'm at a given spot and I'm cool.

Now what you're saying is stress matters and we've got some indication here particularly if the South Texas stuff turns out to be cracking that maybe stress matters more than we thought and might even matter more than effective degradation years.

MR. CULLEN: That would be my opinion, and I'm pleased to get a little bit of validation back here.

MR. ROSEN: Well, I'm just trying to see if I'm putting these tea leaves together here into a pattern.

MR. CULLEN: Well, I think you are, but I'm a materials kind of guy, and in away, I think it's a bit funny for me to stand up here and talk about stress, which is not my business. I mean, I'm saying it's the other guys who should have a lot of business.

I mean, certainly we've got materials problems, too, but, yeah, I think we could benefit a lot more from understanding how the stress varies as a function of the geometry issues that I've talked about and a lot of other things, and then how these two are going to play together to calculate the potential for cracking a plant.

Boy, they're lining up back there now.

MR. ROSEN: We have these ant hills in Texas, fire ant hills, that if you just take a big stick and you poke it once or twice, you want to get out of the way real quick, and that's what I just did.

MR. MATHEWS: This is Larry Mathews.

I guess we've never said stress is irrelevant, and we've never said material properties are irrelevant. We all know that both of those play into the stress corrosion cracking.

All we've said is that we don't know enough about them at the time we were making these rankings and trying to figure out which plants ought to be doing what kinds of inspections; that we would assume they were similar, if you will, and we would rank plants based on time at temperature.

Not to say that if you're below some threshold you can go home and everybody else has got to a problem, but to simply say this is the ranking mechanism to determine at what point people should be thinking about doing inspections.

It's not a model that is, you know, unequivocal; that, you know, if you calculate 8.2 you're okay, and if you calculate 8.3, you've got a pending disaster. We've never said that.

It's just a ranking model. That is all it has been, to help us rank when we ought to be doing what kinds of inspections. Okay?

CO-CHAIRMAN SIEBER: It seems that there is an underlying assumption that the stresses were similar in --

MR. MATHEWS: Yes. All of these nozzles were put together, not identical properties clearly. All of the materials were put together, not identical, but they were all 600 and they were all welded with interference fits and J groove welds, and there will be variation from nozzle to nozzle on the same head and from head to head, and depending on who's manufacturing it.

But we just didn't have enough information to try to home in and say, "Okay. Here is the point, and if you reach here, you've got a problem. Before that, you don't."

It was just a mechanism to help us rank the plants for inspection, and that's all we were really trying to do with the time and temperature, not to reach, you know, here's a threshold. Below that you absolutely don't have an issue.

And stress is a factor in all of the models that we've used in our PFM work, probabilistic

fracture mechanics work. The material properties are, too, but I'm not sure we're modeling everything, but certainly all of this stuff goes into the model. We're not ignoring any of it.

MR. SIMS: Going back to the statement about stresses though and proving it in the industry --

PARTICIPANT: You have to identify yourself.

MR. SIMS: William Sims, Entergy Operations.

The B&W units in general have stress relieved all of their nozzles except for their large bore CRDM nozzles, and they have not had any -- there's only been one B&W nozzle failure in the entire industry.

And the CE fleet, on the other hand, they did not stress relieve the nozzles after fabrication, and there have been, you know, several of those nozzles fail.

So there is correlation between stress and probability of failure due to PWSCC, but I think the bottom line goal of the MRP is to take that part out of the equation because with B&W, the CRDM nozzles that we had, they were actually center ground on the

OD surface of these nozzles. It caused higher stress and actually the fabrication process of straightening the tube cold-worked the tube back and forth and caused high residual stress.

But if you hold everything constant and only change it due to temperature, then we're bounded by the rest of the plant. So I think that's what the MRP's final goal was.

It is highly dependent on stress for each of these locations.

MR. CULLEN: Bill Shack had it right this morning when he said -- he made the point that in these nozzles --

MR. POWERS: This is dubious, to begin with.

MR. CULLEN: It's very difficult in any given nozzle, subject to issue of triaxial constraint, to get the stress higher than the yield stress of that particular nozzle material. True statement.

And since the yield stresses of these nozzles vary over a 20 to maybe 25 KSI range at best, then, yeah, that does confine you to a fairly, fairly narrow range of possible stresses in these nozzles.

You have your choice. You can either have a high stress or you can have a higher stress, and

that also tends to make the stress issue a wee bit secondary to the crack growth rate or temperature issue.

While we're on this business of finite element analysis at the nozzles, a couple other questions that were raised this morning that I can give at least a partial answer to.

One, we talked about leaks and leak rates and who's working on that kind of thing. EMCC, the same vendor that's doing this work for us, is also doing leak rate calculations.

Now, as anybody who has been in the steam generator business can tell you, leak rate calculations have a spread in variability that is just astounding, depending on what assumptions you pump into that. For a 45 mil or 60 mill thick piece of steam generator tubing you can get leak rates which cover a couple of orders of magnitude under otherwise reasonable assumptions.

And if you think that's bad, try doing that same calculation on a .62 inch thick CRDM nozzle with a stress corrosion crack in it, and it gets, you know, pretty dicey.

MR. POWERS: Offhand, I'd say the experimental data on the leak rates for at least one

thickness of steam generator tubes also has huge spreads.

MR. CULLEN: I'm not sure which specific set of data you're talking about, but I'm not at all surprised by that kind of a statement.

All right. So I think I tried to deliver a few minutes ago the message, if you will, that if we had learned a long time ago how to manage the residual stresses in these things, we wouldn't be in such a bad position as we are today.

That's a message that applies going forward as well, and I do know that the vendors who are working on the replacement heads for domestic plants are concerned about that, but there are at least two vendors that are involved. I don't have any detailed evidence from either one about how specifically or what they are doing specifically to mitigate stresses. That is proprietary information. There's a good reason that I don't have that.

But it does raise in my mind the concern about whether or not those two vendors are doing things with a reasonable similarity or reasonable end results, and that brings me to the issue of whether or not we're going to have to be vendor specific in our modeling of these replacement heads.

The last issue that I want to raise is that people, myself included from time to time, talk ad nauseam about the cryptomium like properties of Alloy 690 and the fact that that's going in our replacement heads and that should solve all of our problems.

A lot of other people will say any material placed at or near its yield stress and left in a warm environment for a long period of time is going to crack, and that may well be the case with Alloy 690 also. We just don't yet have the kind of experience that we need to have.

Certainly in laboratory tests it is much better than Alloy 600 and the Alloy 152 is much better than its corresponding Alloy 182, but those are lab tests, and I'm not so sure --

MR. POWERS: When you say "better," do you mean better or slower?

MR. CULLEN: Slower. I don't mean faster crack growth rates. I mean a better quality material, less susceptible, slower crack growth rates, however you want to say that.

But we do have some of these issues, the low temperature degradation and toughness and things that may come back to haunt us in another way that we

haven't yet quite figured out.

Peter, I'm not so sure exactly when you want to break, but I'd like to stir up a couple more ant hills before a break if that's at all possible.

CO-CHAIRMAN FORD: Sure. You're just going to go through this?

MR. CULLEN: This one and if you'd like me to do one more quick one, I can do that.

CO-CHAIRMAN FORD: Okay.

MR. CULLEN: But this one will probably be --

CO-CHAIRMAN FORD: Well, this one will really stir up ant hills.

MR. CULLEN: No, no, it's not.

(Laughter.)

MR. POWERS: I'm sitting here waiting.

MR. CULLEN: I've got something to say about that. I don't like what I hear.

Okay. In the middle of last summer, June or July, I proposed to the industry, specifically to EPRI and Christine King, that we've got so many common interests in the whole nickel based alloy business that we would really benefit from a much more close NRC-industry collaboration on all of these issues.

Of course, that went over very well. We had a great conference call in September. We had another great conference call in November, and out of the November conference call we developed seven particular tasks on which we were going to have NRC-industry collaboration.

Since that time we have not heard word one, and I am here to whine about that very plainly. Any backing that I can get from the ACRS that can be provided to kick this along would be very, very welcome.

I don't need to go into reading all of these things, but, in particular, the failure analysis of the North Anna RPV head. We put this line item into our budgets for 2004-2005. Christine King provided me with Craig Harrington's initial plan for doing this kind of work, and beyond that I have not heard a single thing from the industry until what we just heard today, but I'm not at all sure how it is that we're supposed to collaborate with the industry, if indeed the industry even wants our collaboration, on failure analysis of the North Anna RPV head.

MR. POWERS: Well, it seems to me that that particular one poses real challenges for the independence of the agency. I mean, we've been

reasonably happy with the idea of collaboration in the industry when it consists of going out and getting data, and then each side goes and takes the data and analyzes it as they see fit.

But now you're saying here let's collaborate on the analysis of the data, and I think that poses real conceptual challenges on the proper role of the NRC as an independent regulatory body here.

MR. CULLEN: What I hear in your voice and in your concern, and I would agree with one interpretation that I believe you are making of the word "collaboration," which you know, involves working closely with producing results to which we both agree, losing our independence. That is not at all what I would propose, what any of us would propose.

But I really would like to get the opportunity for the NRC to get its own look at the North Anna head, to do things that perhaps the industry would not choose to do that might serve the particular purposes that we have in mind.

I'm not suggesting that we do a second time what it is that the industry would propose to do. My sense of the word "collaboration" would have a synonym that's more like coordination.

Remember that our business in the Office of Research is to do confirmatory research, and that is one of the things that I think we could do with pieces of that North Anna head.

Another thing that I believe we could do would be to take a look at some of the inspection related questions that we might have specifically. Perhaps the industry would choose to look at them. We would want to look at them also in a confirmatory way or even using our own initiative or for reasons that would fall into the category of anticipatory research.

So I realize that there is an implicit danger when we would begin to work closely with the industry that we might lose our sense of independence, but that is something that we just have to go into these programs and be very careful of.

There are a great many precedents for the NRC working with industry even to the extent of co-funding. I'm not sure what mechanism, what financial mechanism might be involved here. It could range to something as reasonably intricate as co-funding. It could simply mean funding our own independently chosen vendors to execute statements of work that we would put together on our own.

Does that response reasonably satisfy your

concern?

MR. POWERS: Well, I caution that I would work on my language here.

MR. CULLEN: Okay.

MR. POWERS: Because I think you can set this up as a reasonable collaborative program if that program consists of, the collaboration consists of acquiring the data.

But the analysis of the data has to be independent, it strikes me.

MR. CULLEN: Absolutely.

MR. POWERS: It absolutely has to be independent.

MR. CULLEN: No, there is no question about that.

MR. POWERS: And so I'd be cautious about the language that I use here.

MR. ROSEN: As far as backing up your whine, is there a quid pro quo here, I mean, where they send you a quid and you send them a quo?

MR. CULLEN: No, I don't detect that. At least at the beginning what I would like to achieve, and there are a couple of specific things I can mention here in a second as example, I'd like to achieve better coordination maybe is a better word

now, where we might have a topic and the NRC would do these four things and the industry would do these four things, and we would preplan so that they interlace or intercalate a little better.

Now, what I'd like to point out specifically as an example of what I feel is really a lack of collaboration is that we kicked off our boric acid corrosion program -- and I will tell you a little bit more about that shortly -- in the August-September time frame last year. As you've heard this morning, EPRI has put their RFP out on the streets something like five weeks ago, let me say, plus or minus a week or two.

If you look at that industry RFP, it is more broad based than the program that I've put in place at Argonne, but it contains everything in that program that I put in place out at Argonne. Why are we doing this twice? I have no idea.

MR. ROSEN: Argonne will get twice as much money?

MR. CULLEN: No. Argonne won't do their work for the industry. That would be a conflict of interest. Boy, would that get some people excited.

But you know, somebody somewhere is going to do this program for the industry, and they're going

to generate the same doggone collection of data that we're generating at Argonne. I have no idea why.

MR. WALLIS: I'm not sure they will. I mean, it seems to me this might be one of those areas where the science is so poorly understood that having two groups working might not be such a stupid thing to do.

MR. CULLEN: I hear what you're saying, and I think that some overlap in a coordinated program is just fine, but why you would overlap 100 percent of the program is a little bit beyond me.

Now, we are having a few things specifically done by the Argonne people that are not in the EPRI program, I'll grant you, but --

MR. WALLIS: Are they going to do the same experiment, exactly the same?

MR. CULLEN: It looks like it if the vendor responds to the EPRI RFQ in the way that it looks like they should. I would say yes.

MR. POWERS: There's nothing like replication to give you confidence, is there?

MR. CULLEN: I mean, that is --

MR. POWERS: We'd love to see replication even once in this field.

MR. CULLEN: That's one way of looking at

it, but why would you take a six figure program and do it a second time in its entirety? I'm not so sure why.

Okay. Now, the last one I want to point out here is something that in the area of mitigation testing, that for the present time, as I've pointed out here, this is fully an industry effort. Even though we've listed it in the NRC-industry collaboration scheme of things, for the moment mitigation testing is something that I'm quite comfortable just letting the industry go for it as much as they want to.

Industry is going to look at stress mitigation. They're going to look at environmental mitigation, and I just want to sit back and watch what's happening for the time being.

If it comes to a point where we may need some confirmatory research of something that the industry has shown, then we may entertain proposals to take a look at that, but for the moment, this particular item on mitigation is an industry only item.

The nozzle 46 may turn out to be just an NRC item. I'm not sure about that. Again, we don't seem to have the kind of level of conversation going

that I would like to have here, but again, I'll say a little bit more in a few slides from now.

We are harvesting a couple of sections out of the Davis-Besse head in a way that is similar to the way the industry described harvesting pieces of the North Anna head, and one of the pieces that we're harvesting from the Davis-Besse head is Nozzle 46, which had an anomalous UT indication that may or may not be a leak path.

Nozzle 46 also had some circumferential indications in the J weld that were never fully disposed, and I'd like to get about more completely disposing those indications, finding out whether or not they linked up to provide a leaker, and if so, did that leaker create a leak path that, indeed, is the explanation for this, quote, anomalous indication?

The other nozzle that we're harvesting out of Davis-Besse is Nozzle No. 2. That's the one with the small cavity, if you will, "small" being just what, a half an inch in depth, not seven inches in depth. Many people look at that Nozzle 2 as being a youthful version of the -- the cavity around Nozzle 2 as being a youthful version of the cavity that was discovered at Nozzle 3 and may give us some indication, some enlightenment, if you will, on how

these corrosion cavities get started.

All right. Shall we do one more thank or shall we break?

CO-CHAIRMAN FORD: I think we should break here.

MR. CULLEN: Let's do it.

CO-CHAIRMAN FORD: Or else we'll have a revolution.

I'm going to recess until half past. We'll start probably at half past.

(Whereupon, the foregoing matter went off the record at 3:18 p.m. and went back on the record at 3:33 p.m.)

CO-CHAIRMAN FORD: Let's get back into session, please.

Okay, Bill. It's all yours again, please.

MR. CULLEN: All right. Now you all know what's coming from the handout. This next slide always gets a few chuckles, but the message that I want to bring today is that here we have crack growth rates in Alloy 600. Alloy 600, depending on its heat treatment, depending on the normal allowable differences in its chemistry, can take on a wide range of crack growth rates as its normal property.

It's nobody's objective to fit a line

through this data. That is not what this line is. It's not a fit. This line is intended to be representative. It's the 75th mean percentile line of data from alloys that actually exhibited a crack growth rate.

I'm not here to go into a long lecture, a long monologue on how it was that all of this data was generated and qualified, but suffice it to say that this particular slide does show that Alloy 600 takes on a variety of possible crack growth rates, spanning a couple of orders of magnitude.

The main reason that I wanted to put this slide up here is to take a more forward look at the data that's going to be added in a couple of years, and I alluded to that or described that briefly on some of the earlier slides.

I described a couple of Japanese programs that generated data that spanned a fairly wide range of stress intensity factors. None of that data is on this plot at the present time. I can't possibly tell you where that data is going to wind up, but suffice it to say that when the results of the Japanese program have been produced and publicly distributed, that we will have quite a lot more data from that that will appear on this graph.

MR. POWERS: One of the problems with this kind of graph, and we get to see a lot of them in the metallurgical business, and we're assured that there are 10,000 reasons why these things show a lot of scatter, and my colleague, Professor Wallis, will look at a plot like this and say, "Gee, this is proof positive that there are some other variables in this thing," and that's what you've alluded to.

Metallurgists are good at coming up with lots and lots of candidates. What we never see is the multivariate plot in which you say, "Okay. Here are the effects not only of stress intensity factor, but everything else included, and here are the ones that are important and the ones that are not important."

Instead all we hear is, "Here are all of these factors that are important, potentially important."

MR. CULLEN: Just a list.

MR. POWERS: Yeah. We never see a quantification of what's important and what's not important.

MR. CULLEN: I described a, quote, critique of the susceptibility model that I wrote and finished up a couple of months ago and said I would make it available to you all in a month or so. There

are some of those sorts of plots in there that you're describing, plots of crack growth rate versus yield strength, plots of crack growth rate versus grain boundary carbide coverage.

MR. POWERS: But any time you plot against one of these variables, you're going to have a plot like this. What you need is one of the multivariate plots that says, "Okay. I've set up a model. It could be linear or nonlinear, and here is predicted versus observed, and here is my factor analysis on all of those things that I've included to show you which one makes a difference and which ones are never minds."

MR. CULLEN: I suspect you know the discipline called artificial neural network design, ANNs, neural networks.

MR. POWERS: I have stayed away from that assiduously.

MR. CULLEN: I kind of thought when you used the expression "multivariate analysis" that that would be one of the technologies or techniques --

MR. POWERS: It is a technique that people use.

MR. CULLEN: -- that you were thinking of.

You know, they all fall into the general

category of I call it pattern recognition. You can use a variety of approaches. Neural networks is one.

I have just received a draft NUREG report from another contractor that I asked to do a neural network analysis, which is what I think you're asking for, suggesting a multivariate analysis of exactly, well, not this data because the details of this are still proprietary, but we had a reasonably well conditioned set of data from other sources that did have all of the information about chemistry and processing, metallography and things that we wanted to be able to pump into this neural network analysis.

That analysis will be published I will say in a couple of months, the kind of time frame it takes to turn around a NUREG.

So this sort of work is being done. I'm not sure what, if anything, the industry might be doing along this line. Perhaps something. I just don't know.

MR. POWERS: Well, the question is: when does it creep into our discussions of what the research --

MR. CULLEN: Well, it needs to mature, and I think we're a long ways from maturation.

MR. POWERS: Somehow a regression analysis

is not a triumph --

MR. CULLEN: Of modern day technology. I realize it, yeah. It was not exactly yesterday that somebody discovered least squares regression, but the application of that to this sort of database where, you know, everything has variations is something that I think is much more modern day and still at this point less mature and less reliable than, you know, fitting data to something else.

MR. WALLIS: Well, where does this come from? Is this just from this steel, some other situation, or is it for steel under reactor conditions, the environment that you have there or what is it?

MR. CULLEN: Again, to try to be brief because this was described by John Hickling and his colleagues to the ACRS -- oh, I don't know. Tell me when. September, October, some -- June of last year. Okay.

This data was very, very carefully vetted by this Alloy 600 task group. I sat in those meetings and listened to their discussions. Yes, it is data generated for materials that are reactor typical in environments that are reactor typical, and believe me, in the totality of the data that was considered, there

are a far greater number of data points that were discarded as being not valid for inclusion in this database.

MR. WALLIS: Well, if you had more data, you'd just get better coverage of the paper.

(Laughter.)

MR. CULLEN: You're absolutely correct, and that is the point. In a way, we want to know what the full extent of the variability is. We're not looking to have all of this data collapsed onto a very thin line and, you know, at some point in time somebody finding out that, you know, the low liers or the outliers were bad data sets for some particular reason. That's not what we're looking for at all.

We're looking for a plot of data that is representative of all of the materials that could possibly be found in the heads of our domestic plants.

MR. WALLIS: What are you going to do with it?

MR. POWERS: I mean, this is like the heavy section steel program. We'll just keep looking until we find another variable that affects things, and then we can go experiment on that for another six months.

CO-CHAIRMAN FORD: Let me try and help.

I don't think it's quite as bad as you're saying.

The end result is to come up in this case using artificial network approaches, to come up with this multivariable algorithm that you're talking about.

MR. POWERS: Peter, I do not need neural networks to do a multivariate analysis.

MR. CULLEN: But it's one technique.

CO-CHAIRMAN FORD: But by getting the multivariate analysis whether you artificial network approaches is going to come up with this multivariable approach, but it needs the data, the good quality data.

Your objection is if you put some more data on there, you come up with a mass of data. If it's unqualified data, I agree with you 100 percent, but this will be qualified data. If that is accomplished, then he has got hope of coming up with this multivariable algorithm.

MR. WALLIS: Isn't scatter here because of these mysterious heats which are all somehow different because of what has happened to them in the past?

MR. POWERS: Well, that might be one way to --

MR. WALLIS: The variable to quantify.

CO-CHAIRMAN SIEBER: That's one factor.

MR. CULLEN: That might be one way of saying it, but it's not getting to the root cause of the scatter, which is differences in the microstructure of the material.

MR. KRESS: Okay, but do you know what those differences are?

MR. CULLEN: We're getting onto that, and that's another point that I want to make, is as time goes on, the experiments that we do get better and better, and the correlative data that we come to understand is necessary gets to be more and more a part of the overall package.

MR. KRESS: On this plot do you know the differences between the Xes and the squares?

MR. CULLEN: I can't stand here and say that I do. I might be able to dig and, you know, maybe guess that these might be very low yield strength materials as a possible example, and if so, then I would say, well, that probably explains why they're sitting down there at pretty low crack growth rates, and you know, this stuff up here might turn out to be highly cold-worked, high yield with rotten grain boundary coverage. See, now we understand why that's high.

I think we're getting onto this. Do we have it for every data point that's on the plot? Well, I doubt that, but I think we're getting on to understanding what it is that produces these valid differences.

MR. WALLIS: What kind of K do you get in these control rod drives?

MR. CULLEN: Up to about the yield strength of the material, which would be up here in about the 60 --

MR. WALLIS: It is not a yield strength. You have to have floor size and things.

MR. CULLEN: Well, yeah. I'm sorry. You were asking the right question. I was just giving the wrong answer, but --

MR. POWERS: Thirty-five.

MR. CULLEN: Yeah.

MR. WALLIS: Oh, the middle.

MR. CULLEN: Yeah, somewhere in here because these things have .625 thickness to them.

MR. WALLIS: And they're highly stretched. So that's where the K comes from.

MR. CULLEN: That's where the K comes from. Now, you have to worry a little bit about constraint.

MR. WALLIS: -- material. Is it applied K? The applied K from the stress condition, do you know the stress condition well enough to know the applied K?

MR. CULLEN: I think we do, yes. I mean, if you believe the finite element plots that I put up a half hour ago, K is being routinely calculated using those stresses, and you know representative crack lengths through the thickness of the housing.

So yeah, and in fact, those sorts of K relationships are being --

MR. WALLIS: Well, what are you going to do when you get scatter like this? Are you just going to keep on correlating until you try and get something with less scatter?

MR. CULLEN: Well, the goal of this --

MR. WALLIS: -- engineering decision with something like that?

MR. CULLEN: The goal of this particular report was to come up with a proposed curve that could be used to disposition flaws, and the MRP is suggesting that this curve reside at the 75th percentile.

MR. POWERS: This will be the most obscure number to pick as a percentile. A 65.3 or something

like that.

MR. CULLEN: But, again, you have to keep this in the bigger context of there are other conservatisms in the overall analysis that are part of the overall package.

MR. POWERS: Which is the most catastrophic way to do an uncertainty analysis that I can think of.

MR. CULLEN: Well, yes, I realize, but we're trying to --

MR. POWERS: Put conservatisms here, put conservatisms here, and put conservatisms here, and then tell me what you've got at the end. You have no clue what you've got at the end.

MR. CULLEN: You're talking about the difference --

MR. WALLIS: You're talking about the top point, I mean, the highest points. I mean, you've got a whole population of reactors which maybe have steels which lie all over this map. Some of them are going to be up there growing a few centimeters a year.

MR. CULLEN: That is a possibility.

MR. WALLIS: And therefore, you're making decisions based on that.

MR. CULLEN: You are correct.

MR. WALLIS: You have your inspection intervals accordingly.

MR. CULLEN: Again, correct.

MR. WALLIS: Forget about everything else.

MR. KRESS: Or you use a Bayesian update for each specific reactor. State with that one and Bayesian update each one of them.

MR. WALLIS: As you learn.

MR. KRESS: As you go along and learn.

MR. WALLIS: Yes.

MR. KRESS: I agree.

MR. CULLEN: In a slide or two -- I can't remember -- yeah, two slides, I'm going to talk about the susceptibility model, and I think some of the questions that you're asking now might be addressed a little better when I get to that opportunity.

CO-CHAIRMAN FORD: Okay, guys. If you could look at your root thing because the technician is going to play with the quality of this picture.

CO-CHAIRMAN SIEBER: It might get worse?

(Laughter.)

MR. POWERS: Is he going to add some data to this picture?

MR. WALLIS: You mean after the two previous works on that graph, all of the points will

come down?

MR. ROSEN: That's right.

MR. CULLEN: Okay. Let's move ahead just a little bit.

MR. ROSEN: Artificial neural network.

MR. WALLIS: Just tell the guys where to look out.

CO-CHAIRMAN FORD: Thanks, Bob.

PARTICIPANT: That means no more problems here.

(Laughter.)

MR. CULLEN: Okay. Let's forget ahead here a little bit.

The point I'm trying to make on this particular slide is that we have several research programs that relate to the overall CRDM cracking issues other than the ones that I'm mainly involved in, which are stress corrosion cracking. But we have a contract out to look at inspection techniques and probability of detection, issues like that that relate to inspection.

We have the program that I talked about to model residual stresses; another program task aspect that involves developing a probabilistic model, and so on, and --

MR. POWERS: For something called T sub F.

MR. MATHEWS: Time to failure.

MR. CULLEN: Time to failure.

MR. POWERS: You are bright.

MR. CULLEN: And all of these different contract tasks are combined and fed into improved risk analysis models. I want to make again the point here that we are continuing the testing of stress corrosion crack growth rate determination in these relevant alloys and that we are using some materials that we've harvested out of the Davis-Besse head.

MR. WALLIS: Does this probabilistic model have any physics and chemistry in it?

MR. CULLEN: There's a member here of the ACRS who could perhaps comment on that a little bit more.

MR. SHACK: It will have some chemistry and physics in it.

MR. POWERS: All things in life, Graham, are chemistry. So you know that there's some chemistry in it.

MR. SHACK: It will include the mechanistic pictures that we've developed for the residual stresses.

There are things that we know well. I

think we know a lot about residual stresses. We know a lot about K. I think we know a lot about crack growth rate.

MR. WALLIS: About leakage through cracks?

MR. SHACK: We're going up to the place where the leakage starts. We actually know a lot about leakage through cracks, too. You know, it all has to come together.

MR. CULLEN: Let me stress that the probabilistic model that we are developing is to calculate an inspection interval which would be optimized to discover a leak very, very soon obviously after it may emerge after we go through a wall.

So it's not to provide any inspection interval calculations for a plant that already has known leakers in it. What we're trying to do is to come up with intervals for inspection that will help us or assist us to discover leaks as soon as they reasonably can be discovered in a given plant.

MR. KRESS: What do you do when you discover a leak? Go fix it?

MR. CULLEN: I'd rather have the licensee answer that, but I think generally you have the right idea, yeah.

MR. KRESS: Do you fix it the next

shutdown?

MR. CULLEN: Well, of course, they would be shut down at that particular point.

CO-CHAIRMAN SIEBER: NERC does not allow you to operate with a leak except --

MR. KRESS: WE operate with a leak through the steam generator tube. Why is this any different?

CO-CHAIRMAN SIEBER: We didn't operate with a leak. We just didn't operate with leaks. That's the way we interpreted the ASME code.

MR. KRESS: Tech specs allows a certain amount of leakage.

CO-CHAIRMAN SIEBER: Identified leakage, but it can't keep from --

MR. SHACK: If you identify it as a crack in the reactor coolant boundary, it's got to be fixed.

CO-CHAIRMAN SIEBER: There are fair amount of bolted joints or gasketed joints in a plant, some of which may leak. You know, a packing gland (phonetic) on a valve may drip a drop of water on the floor once in a while, and so you're allowed to operate under those circumstances, but you aren't allowed to operate when you have a breach of the physical material of the plant. That's what the code says.

MR. ROSEN: Except for the steam generator tubes.

CO-CHAIRMAN SIEBER: We didn't interpret it that way.

MR. ROSEN: The tech specs interpret it that way.

CO-CHAIRMAN SIEBER: Yeah, I know. There is a tech spec that says you can't have more than a gallon a day or something.

MR. KRESS: So when you detect a crack that's going to be 70 percent through wall by the time of your next shutdown or it's going to -- you're going to repair it at 70 percent through wall or are you going to wait for it to leak?

CO-CHAIRMAN SIEBER: Well --

MR. KRESS: Since you can't have a leak, you've got to decide how far through the wall you're going to let it.

CO-CHAIRMAN SIEBER: When you're operating you aren't going to know.

MR. POWERS: You have flaw evaluation guidelines.

MR. KRESS: Oh, yeah. I haven't read those yet.

CO-CHAIRMAN SIEBER: The only way you're

going to know that you have a leak is when your unidentified number changes, your leak rate number, or you get changes in containment like additional particulate activity or increased humidity. There are indications that you're leaking, but you can't tell where it's coming from. That's why they call it unidentified.

CO-CHAIRMAN FORD: Bill, this construct looks very similar to the NRP construct. Will we have two identical models or two different models or what?

MR. CULLEN: This, I think, falls in the category of confirmatory research.

CO-CHAIRMAN FORD: Well, what happens if it gives a different answer?

MR. CULLEN: We need to resolve an issue like that.

CO-CHAIRMAN FORD: It's bound to give a different answer.

(Laughter.)

CO-CHAIRMAN FORD: I guess I'm wondering what do we do in a case like that. Do you have an argument, a discussion?

MR. CULLEN: I think I don't have an answer to that right now. It's kind of a wait and see once we get there kind of a thing.

CO-CHAIRMAN FORD: Now, the industry are saying that they will have this for Alloy 600 for cracking by the middle of this year. What is your time scale?

MR. CULLEN: Well, this is a work in progress. I think the time scale is roughly the same, but it is definitely a work in progress.

CO-CHAIRMAN FORD: Okay.

MR. SHACK: South Texas may cause some upset to the model.

(Laughter.)

MR. CULLEN: Okay. Let's --

MR. SHACK: Because the model doesn't predict South Texas at the moment.

MR. CULLEN: Let's move on here a little bit. I've mentioned a couple of times now that I've been a couple of months taking a look at this susceptibility plot. As we've heard a few times today, the current model depends only on time at temperature, and the current model, I would have to admit, and it's very easy to see, is doing a very nice job of projecting when the plants will develop obvious leaks.

All of the red squares down here at the bottom are bare metal visual observations of leaking

CRDMs. So the model works. That's indisputable.

There are a couple of orange triangles over here which are NDE cracks, discovered by NDE and repaired. So you know, where these boundaries are maybe something that could be discussed further.

Remember, of course, this is a statistical distribution. So you know, you're going to find some things elsewhere other than right up here at the upper tail.

MR. WALLIS: What does plant ranking mean here?

MR. CULLEN: Oh, we just number from the plant with the highest number of EDYs to the plant with the lowest number.

MR. WALLIS: Then it should be a monotonically increasing curve.

MR. CULLEN: And it is.

MR. WALLIS: It's not. It has got wiggles in it.

MR. CULLEN: I think if you take a look, every data point is a little further to the right. Now, you won't see any back-ups except for something like this which is in there twice.

MR. WALLIS: It should be up as well if it's just a ranking based on EDY.

MR. MATHEWS: The growth mark plant ranking, it was ranking as of a given date and time, and the plots were the inspections for that time of the inspection.

MR. CULLEN: Yeah, that's true.

MR. WALLIS: Ah, that's the only difference.

MR. CULLEN: I'm thinking maybe what's confusing things is like that orange triangle also has another data point out here for that same plant. You know, if you eliminated the duplicity where a plant had --

MR. POWERS: The duplicity. Let us eliminate the duplicity at all opportunities.

MR. CULLEN: If you eliminate the double counting of the plant? Okay.

You know, some plants had an observation and disposition at one point in time, and the same plant had another observation and different disposition at a second point in time. Kind of belaboring that in order to straighten it out.

CO-CHAIRMAN FORD: I know we asked the question why the discontinuity in the curve up here and, boom, like that.

MR. CULLEN: Yep.

CO-CHAIRMAN FORD: And I know the answer was given, but I've forgotten what it is.

MR. CULLEN: Well, these are all cold head plants. So they build up EDYs very, very, very slowly. I'm not sure what that plant is. You know, everything has an explanation, but you know, these are basically all of the cold head plants. These are all of the really hot head plants.

CO-CHAIRMAN FORD: But Graham's point is if you have the same algorithm here, it should be a smooth curve.

MR. CULLEN: I wouldn't say a smooth curve.

MR. WALLIS: The different times apparently. They ranked them at different times when they calculated EDY, but it should be essentially a smooth curve. There's no new information involved by plotting plant ranking. It's really on the basis of EDY, the points to the right.

MR. CULLEN: Yeah. The worst plant is the number one plant, the worst in terms of the maximum EDY, and the best plant is up there.

CO-CHAIRMAN FORD: Okay.

MR. CULLEN: It's just a convenience to plot things that way.

Okay, but the point that I want to make here is that, you know, in a statistical basis we can all envision the day perhaps where a plant down in here is going to develop a leak, and we may know about this already, but I'm not going to stand up here and mention names.

So you know, there are other factors that are going to affect this susceptibility ranking one way or another. Some of these low plants are going to develop a crack, and we're going to have to figure out why.

Some of these plants up here in the high ones, maybe that star right there which so far is a good plant, no observations from NDE. You know, this may go on out as a green star for a long, long period of time, and we're going to have to come to some way of understanding why that is.

Again, it's not my role to take a plant position, but I can well imagine that licensee asking for some sort of relaxation from the NRC. You know, why are we driving ourselves nuts just because we're in the high susceptibility category? But, you know, we've got other rationale for why we're staying clean.

So I can see that some of these other factors that I've mentioned, yield strength, grain

boundary carbides, actual measurements of stress corrosion crack growth rates in nozzle materials, might be something that we might want to take a look at and have some consideration of going forward.

Okay. I'm going to launch into kind of the last part of this, but I actually thought the last part might generate more questions than the first part. If that's the case, bring in the sleeping bags.

Okay. The Davis-Besse licensee, FENOC (phonetic), has completed the experimental work on the investigation of the cavity dropout from the Davis-Besse plant, and they have provided that information to us at the NRC, and I do have explicit permission from them to show you the pictures that I'm going to show you.

And the reason that I want to show some of these pictures to you, some of the descriptions of what they found metallographically and fractographically is because this information plays directly into the research programs that we're conducting here in the MEB. Basically they looked at the axial and circumferential cracks in the J weld and also in the small section of the nozzle that's still Nozzle No. 3 that remained.

They took a look at the cracks in the

clad, and they took a look at the walls of the cavity, and I'm going to show one example in all four categories: the axial crack in the nozzle, axial crack and circumferential cracks in the J weld, the cracks in the clad. the fourth thing is the walls in the cavity. Because all of those things are important to some of our research programs.

Okay. As an example of what they did -- and all of this work was conducted won in Lynchburg by BWXT -- here's a portion of the cavity. Now, actually they have sliced essentially horizontally through the head and removed what would have been the top part of the head at about two thirds of the way up or at the point where the nose of the cavity was, actually had its greatest extent.

So not to belabor or point out the obvious, but the Nozzle No. 3 was right in here. The zero degrees is always downhill for reference, and you'll need that point of reference as I go through and talk about all of this.

The largest cracks in the nozzle were very near ten degrees, right about there, and that is the one that was spewing water into the cavity and causing this corrosion.

There's another very large crack, actually

somewhat larger crack, at 180 degrees which was non-leaking.

MR. WALLIS: Could you tell me again while I'm looking at them? Am I looking down into a hole?

MR. CULLEN: Yes. You're looking from the top down.

MR. WALLIS: It looks as if it's coming out to me. It's actually going away from me.

MR. CULLEN: It's going away from you, yes. That's hogged out or dug out. The illumination is a little bit --

MR. WALLIS: And you're looking at the bright cladding.

MR. CULLEN: Yes. This, of course, is the exposed cladding that has been cleaned up now, and it's shining back at you. This is the low alloy steel. This is the J weld. There's a very nice picture of that coming up in the next slide.

MR. WALLIS: But the boundary is very sharp on the surface of --

MR. CULLEN: No, no. Remember if my hand is describing the thickness of the head, we've sliced through that at approximately two thirds of the way up.

MR. WALLIS: Oh, through the head.

MR. CULLEN: Yeah. So there's another matching piece that would sit on top of this, and if you could see the outside of that, you'd be looking at the original top of the head.

MR. SHACK: Oh. The 180 degree crack was also through wall and metallographically was a larger extent than the ten degree crack?

MR. CULLEN: One, point, two inches versus 1.1.

MR. SHACK: Was it through wall?

MR. CULLEN: Yes.

MR. SHACK: Okay. Why do you label it non-leaking?

MR. CULLEN: Because it didn't leak. There's no corrosion. There's no leak path.

PARTICIPANT: Non-eroding at any rate.

MR. CULLEN: If you look at this wall, it's as pristine as something like that should look.

Okay. Now, this is a picture of a little section of the J weld. Now, remember this surface has never been seen before by man or woman. This is the surface that was exposed by the corrosion of the boric acid.

Here is the low allow steel that I've labeled over here, and this is J weld deposit, and

this surface, of course, was in intimate contact with carbon steel once upon a time.

So I'm just showing this as kind of a --

MR. WALLIS: But the J weld was not touched. That's --

MR. CULLEN: The J weld was not attached. That is correct.

MR. WALLIS: Is it similar material to the clad or is --

MR. CULLEN: No. Clad is basically a 308 stainless steel, something that looks vaguely like --

MR. WALLIS: The stuff that you weld stainless to carbon with?

MR. CULLEN: Yeah, this is the Alloy 182 that we've talked about repeatedly this morning.

MR. WALLIS: I didn't know what it is.

MR. CULLEN: Okay.

MR. ROSEN: It doesn't get attacked by boric acid.

MR. CULLEN: That's correct, and the stainless steel clad does not seem to be attacked wither. The reason that this section was made at this point was that this distance here happens to be the very thinnest that the clad got anywhere within the cavity. If memory serves right, this is .208 inches

thick right here at this little tucked in corner.

MR. WALLIS: This is a place where the hole is pretty narrow. So it's really in the corner. It goes into a --

MR. ROSEN: Maybe you can go back to the picture before and show us roughly from above where that is.

MR. CULLEN: Okay. You're looking at this piece right here.

MR. WALLIS: It's amazing how narrow that whatever you call it is.

MR. CULLEN: Yeah. Well, you know, it was corroding.

MR. WALLIS: It would carve out in that pattern is really remarkable that you would cut so deep and so narrow.

MR. CULLEN: Well, I mean, the depth of the cavity was almost seven inches.

MR. WALLIS: I know, but isn't this a remarkable pattern?

MR. CULLEN: Well, it certainly is interesting. Yeah, "remarkable" is a fine word. Interesting, stupendous.

MR. POWERS: Elicited a lot of comment.z

MR. ROSEN: Earth shattering, curious.

MR. CULLEN: All of these kinds of things. Curious. All right.

MR. WALLIS: One has to really think about how that pattern could be developed.

MR. CULLEN: Are you talking about this pattern right here?

MR. WALLIS: Oh, no, no, no. The pattern of the hole, the --

MR. CULLEN: Oh, the geometry of this --

MR. WALLIS: Yes.

MR. CULLEN: -- overall cavity at that location. Well, in the same sort of line, I think, there is a little bit of a corrosion undercut right here. Originally I actually thought that maybe there would be a substantial undercut. That turns out to be not true.

This is almost the undercut in its entirety. If I had included more of the picture, it kind of goes up very quickly up along here.

This photo is a 180 degree reversal of this because of the difference in the type of camera. This is an ordinary camera. This is a telegraph. So this little undercut is actually that little thing right there that you can see.

MR. ROSEN: And there's a crack extending,

right?

MR. CULLEN: No, that is not a crack. That is just simply the boundary between cladding and low alloy steel. It does look sharp. I agree. Visually it looks like a crack, but it is not a crack.

MR. ROSEN: Looks like a crack to me.

MR. CULLEN: No. Take my word for it. It's not.

MR. WALLIS: Is there any pattern on the low alloy steel that indicates convection patterns or anything?

MR. CULLEN: We're going to get that in the second and third slides from the end.

Okay. As I've said two or three or four times now, we're doing actual crack growth rate testing of the Alloy 600 that was in Nozzle No. 3. This is some metallography on that nozzle material.

This is the remnants of the non-leaking crack, the longest one, that was in Nozzle No. 3. Basically what happened, as the licensee was, on March the 8th, boring up to prepare this nozzle for its repair, they got up to a certain point where they had actually gotten rid of three of the four cracks that were in this nozzle when it tipped on them, but there was the tail end of that fourth and longest crack, the

uphill crack. The one at 180 degrees was still partly in the nozzle. So that's the one that still remains, and that's what you see. Right there is the tip end of that particular crack.

Looking at the metallography of this, and I also would like to mention, and it comes out later actually, the yield strength of this particular material is known, and I would call it moderate, in the middle of the range of yield strengths that we know for this particular material, and the grain boundary coverage is pretty good.

That darkened line right there is basically carbides all along this particular grain boundary. If you do an analysis of the carbides, you get this huge chrome peak right there. Over here there it is right there. You can see it's nothing like what it is over here.

On the other hand, here's the iron peak and here's the nickel peak, and they are virtually nonexistent over here. So there was essential chrome depletion nearby and chrome carbides right on the grain boundary, very low in iron and nickel, but the matrix has the normal Alloy 600 chemistry.

Basically my message here is that considering the chemistry of this material, the yield

strength of this material, the fact that the micro hardness traverse on it is fairly flat, basically this is pretty good Alloy 600.

MR. WALLIS: So downhill on this thing is the furthest extent of the hole, is downhill, isn't it? So the debris from the hole is flowing out of the downhill edge presumably.

MR. CULLEN: At the downhill edge, yeah. That is not this crack that we're talking about here. This is --

MR. WALLIS: Going back to the previous picture, yeah. It's flowing -- no, no, the one before that. This is uphill somewhere. It's flowing out over there. It's coming out on the right.

MR. CULLEN: It is coming out at probably about this angle right here, pretty much, you know, coming out of the ten degree crack, and I would say pretty much coming --

MR. WALLIS: Oh, that's where it's coming out of the crack, from the crack.

MR. CULLEN: Yeah.

MR. WALLIS: Okay. So that's also on the side of the most erosion or corrosion.

MR. CULLEN: Right, but the crack that I'm showing in that slide, two slides ahead, is up back

here. That's the only crack that remained after the nozzle tipped over on them. It's the only one that we have to look at. The downhill crack, the ten degree crack, the leaking crack is a goner.

Okay. This is a metallograph of that stress corrosion crack that you saw in a normal photo on the previous slide. I'm showing this simply to reinforce what we talked about this morning, the tortuosity of --

MR. WALLIS: The crack growth rate you mentioned is what, the actual distance with a straight line between the end?

MR. CULLEN: No, it's the linear crack growth rate. It would be what you would see if you looked straight down normal --

MR. WALLIS: When it wanders around like this, doesn't K vary?

MR. CULLEN: On a highly, highly --

MR. WALLIS: -- then it must be changing its K all of the time.

MR. CULLEN: But fracture mechanics don't think of the driving force behind a crack in that regard.

MR. WALLIS: Oh, they don't?

MR. CULLEN: You may be correct on a very,

very local basis, but fracture mechanics is a more global analysis of crack driving forces.

MR. WALLIS: But the K forms sort of an analysis of an ideal crack and the square root law for the stress distribution.

MR. CULLEN: That's correct.

MR. WALLIS: Is that the radius? That's where K comes from.

MR. CULLEN: That's correct.

MR. WALLIS: And this doesn't look anything like the model that K is based upon.

MR. CULLEN: That is --

MR. WALLIS: How can you use a K?

MR. CULLEN: Well, in a highly local way that's true. It doesn't look like, you know, a linear crack with an infinitesimally sharp notice.

MR. WALLIS: The tip, it's still doing the same thing. See?

MR. CULLEN: What we do know is that cracks that look like this still, if you will, observe the laws of fracture mechanics.

MR. WALLIS: Except that you can't correlate the data.

MR. CULLEN: No, let's not go that way.

Okay. If you open this crack up, this is

what you see: classic intergranular stress corrosion cracking. You couldn't get a picture that's more textbook perfect than that, and that's the reason that the licensee did this, is to prove, if you will, that a stress corrosion crack in a field typical nozzle really looked like that.

It's not the first time that we've been able to do that, but it's helpful to know that.

MR. POWERS: Maybe you should tell me what I am not seeing here.

MR. CULLEN: Well, I'm going to sidestep that question because I think what we are seeing is what we would expect to see.

MR. POWERS: I mean, what you're saying is because you see lots of dodecahedral kind of structures, you're breaking in between the cracks.

MR. CULLEN: Exactly right. So this is classic textbook IGSCC. You don't need another explanation.

MR. WALLIS: Nothing else looks like that?

MR. CULLEN: Now we're getting into a Pandora's box. Are you looking for an answer to that question?

MR. WALLIS: Well, yeah. You said this was now we know sort of for certain that this is an IGSCC

crack.

MR. CULLEN: Yeah.

MR. POWERS: I mean, almost ipso facto because it's obviously intergranular and it's obviously a crack. He doesn't know that stress corrosion caused that crack.

MR. CULLEN: Well, you know, it has been suggested, as an example, that thermal fatigue may drive some of these cracks in the head. We don't see any evidence of that, and I'm happy for that. I mean, that would complicate our lives enormously.

So, I mean, it's those sorts of things that we don't see that gives me some ability to understand better what it is that is driving this thing.

MR. SHACK: You don't see the river patterns that you would get if you saw some sort of hydrogen embrittlement.

MR. WALLIS: That's some tip.

MR. POWERS: The thing that puzzles me about this crack, the speakers that precede you a lot said, "Gee, these cracks are very tight."

And I look at that and say, "Gee, that doesn't look like a tight crack to me."

Is that a tight crack to you?

MR. CULLEN: No. You're not looking at the crack tip though. You were looking at the crack tip.

MR. WALLIS: There is no crack tip. There are thousands of crack tips.

MR. CULLEN: That's true, and that reinforces the point that was made by another speaker this morning, is that stress corrosion cracks typically branch all over the place and give you lots of NDE signatures to look at.

Now, back in here, you know, this is the original ID, and so, yes, the crack has a large opening at this particular point, but if you come down at the end of it and you take a look at some of these tips, you know, they're pretty tight. Up in here it looks open. I'm not so sure we're really looking at the tip of the crack.

And remember this is just a slice.

MR. POWERS: I understand.

MR. CULLEN: And the tip may be who knows what?

MR. POWERS: In or up in the material that you --

MR. CULLEN: Yeah. So I don't think we should be misled by what appears to be a certain

openness in the crack enclave.

MR. POWERS: But it is that, those stringer kind of things that you see out there that are being described as tight.

MR. CULLEN: That's correct.

MR. WALLIS: Now, tell me about stress corrosion. That corrosion part must imply some kind of chemistry going on. There's something going through the crack which is causing this to pop through?

MR. CULLEN: Well, I could launch into a long monologue at this point, but --

MR. WALLIS: No, but there is something in the crack? The environment makes a difference?

MR. CULLEN: The environment absolutely makes a difference, yeah. Now, exactly micro mechanistically, micro chemically what's going on, let's not go there.

MR. WALLIS: The environment has to diffuse an awful long way through those metal cracks to relate what's in there to what's back in the reactor.

MR. CULLEN: Well, but remember this was solid metal.

MR. WALLIS: I know.

MR. CULLEN: So solid metal with water out here, what happens when that metal opens? I mean something has got to get sucked up in there and --

MR. WALLIS: There must be a tremendous gradients in the chemical environment going on in there.

MR. CULLEN: I would tend to agree with you. There probably are, and that's been several thousand theses generated on that issue.

MR. WALLIS: Did they ever resolve it? Do you have a model for it?

MR. ROSEN: Yeah, there are lots.

MR. CULLEN: Lots of models. Very, very difficult to prove. Now you get into how do you sample the environment that's up there in the crack. You may be aware there's some attempts been made to sample the environment in the crevice in steam generator tubing, tube sheets, but all of this sampling business is very, very difficult.

MR. WALLIS: You probably influence it just in trying to sample it.

MR. CULLEN: Yeah.

MR. WALLIS: You change what's there.

MR. CULLEN: You know, when you go sample something, you probably are extracting a volume of

material that is totally disruptive to the total volume of the crack.

MR. WALLIS: So what's in the crack? There's a liquid in the crack?

MR. CULLEN: Presumably.

MR. WALLIS: Where did the material go that disappeared from the crack?

MR. CULLEN: I don't think anything has disappeared.

MR. WALLIS: Well, how is it opened up then?

MR. CULLEN: Stress.

MR. WALLIS: It has opened up. It has moved. It has moved apart.

MR. CULLEN: Yeah. There's a displacement.

MR. WALLIS: There's a displacement. Okay.

MR. CULLEN: Okay. I just wanted to show this as examples of the cracks in the J weld, and again, we have got sections of the J weld at Argonne. We're going to be doing our own crack growth rates on this material.

Going now to the clad --

MR. WALLIS: That was wonderful.

MR. CULLEN: I'm sorry?

MR. WALLIS: That's wonderful, I said, wonderful.

MR. CULLEN: I still didn't hear.

MR. WALLIS: It's wonderful, the shapes of these things.

MR. CULLEN: Oh, okay.

MR. WALLIS: Remarkable.

MR. CULLEN: Well, you know, initially the first observation that was made of the exposed clad did not provide any indication that there were actually cracks in the stuff. The black right here was originally low alloy steel. Okay? So this surface here, absent a little bit of wastage that has occurred, was the surface that was in fused contact with the low alloy steel. Okay? The surface that is in contact with the reactor coolant is down here somewhere. I don't know where. This is only a part of the thickness of the clad. So this is the exposed.

So this was after the cavity developed highly concentrated boric acid solution, probably at a temperature approaching the boiling point, the normal ambient pressure boiling point, say, 200 and something degrees Fahrenheit.

And these cracks, if you open them up as

we have right here, the crack path is interdendritic in a weld that is the analog to intergranular stress corrosion cracking.

MR. WALLIS: Well, why do you say it was 212? Doesn't the boiling point go up on --

MR. CULLEN: It does. Give me a number.

MR. WALLIS: It goes up quite a lot.

MR. CULLEN: I'd be happy with 215. I don't know. We don't know the concentration of boric acid. That's why, you know, I've got to hesitate on that.

MR. WALLIS: It's got to be pretty concentrated.

MR. CULLEN: Pretty concentrated is definitely the answer, but what the boiling point elevation is I'm not sure, but the message I'm trying to deliver there is not 605 degree temperature water. It was down quite low, and we do know that low temperature, concentrated boric acid solutions will corrode the low alloy steel, and that's why 40 pounds of it disappeared.

MR. ROSEN: I didn't just disappear. It just kind of flowed out. It wasn't magic.

MR. CULLEN: It was not magic. That's true.

The message that I was trying to deliver is that initially we didn't know that these cracks existed in the clad. So the safety analysis, structural integrity assessment that we had originally tried to do used the entire thickness of the clad on an assumption that the clad had its original thickness. Okay?

But now, just a few weeks ago when these photographs were presented to us, we found out that we've got cracks in this stuff. Well, the good news is that the cracks are, quote, only about 40 to 60 mils deep in clad that is between 200 and 300 mils thickness depending on where you are. So they only go a fourth or a fifth of the --

MR. WALLIS: Only produce the stress concentration and all of that kind of stuff?

MR. CULLEN: We're in the process of trying to calculate that right now. It will be two or three more months before we get to the bottom line answer.

MR. WALLIS: Very interesting because the assurance we were given was that this thing was a long way from disaster.

MR. CULLEN: We still believe that to be the correct answer.

MR. WALLIS: Just include these cracks in that.

MR. CULLEN: Even including the cracks, we still believe that that's the correct answer.

MR. ROSEN: Now, this stuff was yielded, right?

MR. CULLEN: There was a bulge. This is a point I have to be kind of careful with right now, and it is going to be part of our ultimate dispositioning of this thing. It is correct that there was a bulge in the clad, a bulge of the licensee tells us approximately an eighth of an inch. We take that to be reasonably accurate. We've got the data. It's reasonably accurate.

However, the interesting thing is that these cracks which are located right on top of the bulge show no evidence of plasticity at all, zero. We don't quite understand that yet. We're working on that, but it is very, very perplexing that these cracks appear to be driven entirely by intergranular stress corrosion cracking, no evidence of ductility, plasticity, void formation, whatever you want to look for that would give you some indication that there was plastic deformation going on in addition to stress corrosion cracking. We see no evidence of that, and

it is, very frankly, a dilemma

MR. ROSEN: Because there's a bulge.

MR. CULLEN: Because there's a bulge. Now, that bulge, it was not a case of the cracks growing and then the bulging because we would see rounded crack tips.

MR. WALLIS: This is the bulge which is left. It isn't the plastic deformation alone. The elastic deformation would have made a bigger bulge on top of that.

MR. CULLEN: Well, we wouldn't see the elastic deformation. No, that would have snapped back when the --

MR. WALLIS: I know, but it would have been there. It would have been there on top of.

MR. CULLEN: Oh, it would have been there on top of that. That's absolutely true, but, you know, to a much --

MR. WALLIS: So it would have opened the crack some more maybe.

MR. CULLEN: Well, that, you know, stress corrosion cracks are driven by the elastic stress field. Generally stress corrosion cracks don't like plastic stress fields, plastic strain. That tends to blunt them and stop them. We don't see any evidence

of that.

And it's very, very hard to imagine that the cavity opened, the bulge occurred, and then all of these cracks got started. That's not a very comfortable scenario. I mean, it just doesn't sit well.

CO-CHAIRMAN FORD: So this is relevant to the ultimate safety analysis, this particular incident.

MR. CULLEN: Yes.

CO-CHAIRMAN FORD: What does it tell us about --

MR. CULLEN: Can I defer your question for one or two more slides? Because there's another message coming.

CO-CHAIRMAN FORD: Okay.

MR. CULLEN: There is a message about that.

CO-CHAIRMAN FORD: Okay.

MR. CULLEN: So I mean these other things are just more of the same, but one part of the message -- well, I guess I've belabored that point. There's no tearing even near the bulge.

I'm sorry. I didn't mean to switch quite so fast, but we'll leave it. That's okay.

Another part of the message, the licensee made measurements on the depth of those cracks on the remaining ligament. No matter where the cracks occur in the clad, no matter what the thickness of the clad at that particular location, there's about 200 mils of clad remaining intact, in other words, intact, unflawed thickness of the clad.

Why did those cracks all pop in? I shouldn't use that. Erase the tape.

Why did those cracks all develop, move down, and with 200 mils of clad remaining stop? We don't know.

Could it be they are driven by stress? Possibly, and the stress just ran out of gas.

MR. WALLIS: Shut down the reactor.

MR. ROSEN: That could be.

MR. CULLEN: Well, but remember this cavity probably did not develop overnight, and these cracks are distributed throughout the cavity. So you've got to assume that the ones near the nozzle probably got an early start.

MR. WALLIS: They should be longer.

MR. CULLEN: They should be longer, but they're not. I mean, all of these cracks go down and leave about, you know -- so my guess is that they were

probably driven by some sort of residual stress, and we do know that when you apply cladding to low alloy steel you create a tensile stress field as the cladding contracts and solidifies and cools.

So it makes some sense that we do know there is a reasonably thin layer of residual stress in the clad. So maybe the crack got nucleated, got started, grew until it just ran out of stress gas, so to speak.

Another possibility is that it's temperature controlled because remember you've got 605 degree water on the underside and you've got 200 degree Fahrenheit, 218, whatever you want to say concentrated boric acid solution on the top. So you've got a temperature gradient through the clad, and maybe that influences crack growth rate in clad.

We don't know because we've never seen stress corrosion crack growth rates in essentially, I mean, pure water. Agree it has lots of boric acid in it, but no other contaminants.

MR. WALLIS: It would be worse, wouldn't it? I mean if it's colder on top it would tend to open up more.

MR. CULLEN: You would tend to think so, yes. I agree with that, yeah.

Lots more questions than we have answers right now.

Okay. Peter, we're getting a little closer to the answer to the question that you were trying to ask me a few minutes ago.

MR. WALLIS: Well, the big question for me has always been why was the hole the shape it was. Have you got any handle on that at all?

MR. CULLEN: I don't at the present time. I'm not sure where the industry program that we heard about this morning is going to take us, but it might take us in that direction.

We may learn -- I say "we" in the sense of NRC RES -- may learn something from our probable investigation of the cavity around Nozzle 2 and the shape that that had relative to the crack that was in Nozzle 2. We just don't know the answer to your question in a sentence today.

MR. WALLIS: Why did it make a cavity instead of just a river or sort of an erosion pattern under the river?

MR. CULLEN: Don't know.

Okay. What we're looking at here is a normal photograph, J groove weld. The difference in coloration here is probably due just to the etching.

It doesn't mean anything particularly about deposits to the welds or anything like that, and this is the clad. This, of course, is where the cavity was, up in here, and this is where reactor coolant was down here.

Here's a little bit of an expansion. What I'm getting at and you'll see much better in the next slide, is there's a bunch of little stress corrosion cracks right over here in the corner as well. There they are metallographically now. This is the clad, and you can see that there's quite a large number of very fine, relatively short cracks, some of which actually penetrate the boundary. This is J weld down here. This is 308 stainless -- I'm sorry -- yeah, that's right, 308 stainless up here, 182 J weld down here.

This type of cracking only occurs very, very near the J weld. So I'm presuming that it has got something to do with the residual stresses that were set up when the J weld was deposited, and again, they only run down to and just barely into the J weld, and they seem to stop more or less, you know, where that boundary is.

The point that I want to make here, and to some extent in the previous slides at the cracks in the cladding is that we have known; you folks in the

ACRS are well familiar with irradiation assisted stress corrosion cracking in stainless steels, sensitized stainless steels. You're very familiar with boiling water reactor cracking problems in sensitized stainless steels, but we do not generally see stress corrosion cracking in stainless steel weld metal in the weld.

We usually see it at the heat affected zone or in some other sensitized part. We don't generally see stress corrosion cracking in weld metal, and here we have it in abundance.

We also have some IGA in abundance, intergranular attack, and some wastage, some grain dropout. These are things admittedly we've got a very off chemistry situation here with highly concentrated, probably highly oxygenated boric acid solution.

But, again, we've never seen this sort of a thing, and some of the people, some of the researchers, science regulators that I have talked to about this feel like this may become an issue, something that we might have to take a deeper look at going forward from here.

Whether this is the precursor to more stress corrosion cracking issues in a material that we thought was going to be fairly immune to this stuff I

don't know, but that's the message that I wanted to deliver here, is that --

MR. WALLIS: You've got this thin stainless steel there. You've got a tremendous heat flux through there presumably --

MR. CULLEN: Yes.

MR. WALLIS: -- compared with what you had originally. So you have to supply a lot more liquid to keep it cool.

MR. CULLEN: That's absolutely correct.

MR. WALLIS: Someone has done all of those calculations and figured out what was going on?

MR. CULLEN: In MRP 75, I think it's Appendix C, you might take a look at that. While I'm not a TH kind of guy, I can read through that enough and see through that. I really believe that they have got the right handle, the right model for why liquid at 200 and something degrees accumulated in that cavity. I think I can understand that even though I don't understand the complexity of the calculation.

And I would recommend that. It's good reading, good background reading.

Okay. We had a question just a few minutes ago about the walls of the cavity and what do we see on the walls of the cavity. So this is the

low alloy steel now, and actually I've changed.

If you think back to the very first slide in this series where I showed how a typical hunk of the cavity had been sectioned up every which way from Sunday and I said the thing had been split horizontally, well, now we're looking at the top part that was lifted off, but we're looking at the top part from the cut side.

So this is the opening that was visible to the licensee on March the 8th. Okay? And this is the nose, the deepest penetration of the corrosion, and this is the saw cut, horizontal or nearly horizontal surface.

All right. So three examples. This then would be about at the 180 degree or downhill side. The leak, in other words -- the orientation has changed -- the leak is, you know, back up here and streaming water pretty much straight into the nose of the cavity here.

And we have side walls. Again, if you're standing at the top dead center of the head looking down at Nozzle No. 3, this would be to your right side. This would be to your left side, and you can see that there are slightly different morphologies, more of the sort of pock marking on this left-hand

side, more of the striations and sort of linearized texture on the right-hand side, and straight ahead almost nothing but pock marks.

So people will look at this and say, "Oh, my gosh, that is classic flow assisted corrosion." I personally have a problem with that because I don't think .01 gpm squirting through this murky solution of concentrated boric acid and hitting this wall seven inches away is going to have very much flow assistance impact to it, but you know, I've heard that spoken by some people in --

MR. WALLIS: Well, if the water is more like boiling, I would think is going on in this hole.

MR. CULLEN: That is definitely true. I mean, you've got enormous what you just said a few minutes ago: a lot of heat flux coming through that quarter inch thick piece of clad down there. So a lot of the stuff spewing into here.

As it turns out, if you look at Appendix C, 80 percent of the water that's coming out of the crack at 0.1 gpm, about 80 percent of it goes off immediately as steam and only 20 percent of it has a chance of remaining as liquid. But of that 20 percent, a whole lot of that is going to be boiled away.

But there's still enough. I mean, the leak rate is enough, according to the calculation that you still have residual aqueous solution.

Early on the people were fussing with the possibility of molten boric acid, a kind of gooey, gummy concoction. I don't see any chance that that existed in any amount that would make any sense or any difference.

Okay. I put this slide up because in the Argonne program we are doing wastage measurements in both quiescent and slightly flowing environments. So the kind of attack that we get may, indeed, look like some of this stuff. I hope it does because then we'll kind of have a rationale for why these sorts of patterns developed.

So, you know, it's nice to have actual photographs of what happened to this low alloy steel as a way of correlating or validating our laboratory investigations.

The same sort of thing, the last slide in this particular series. Again, this is a cross-section that shows how rough that low alloy steel surface was.

Two enlargements that show you what some of these dimples looked like in cross-section, and

again, I'm just showing this and waiting to see what the Argonne results --

MR. WALLIS: Those dimples have nothing to do with the micro structure. They're too big.

MR. CULLEN: Well, you know, my experience in similar environment -- I won't say exactly similar environments -- but concentrated acid, concentrated sulfate environments of low alloy steel is that these sorts of dimples usually develop where you have an inclusion that acts as a local corrosion accelerant.

So, yeah, they are related to the micro structure. The point that the licensee is going to make is that these depressions are related to this layering, this segregation, banding, whatever you'd like to call it. You can see this cutout right here is kind of related to these bands. This here is related to that black band. You have another --

MR. WALLIS: This looks more geological all the time.

MR. CULLEN: Oh, yeah, yeah. But you know, this banding is related to the inclusion content in the alloy and does provide what I think is a reasonable rationale for why you get the highly textured surface, the voiding.

MR. WALLIS: Well, you've almost got the

old man of the mountains up there.

MR. CULLEN: Yeah, yeah. You can let your mind run in a lot of directions on some of those profiles.

Okay. So talking a little bit now about the specific program that we've got in place out at Argonne, I want to stress that although we started this program as a result of finding this massive corrosion at Davis-Besse and as a consequence of the fact that I really couldn't find data that we needed to have to help with the dispositioning and the understanding of that right at the beginning, we developed this program at Argonne.

There is a lot of work on the generic description of corrosion of pressure boundary alloys and concentrated boric acid solutions, low alloy steel, Alloy 600 and 182. I think we've going to try to get some 308 in here as well.

So even though the program was spurred on, if you will, by the findings at Davis-Besse, we've designed this program to be very generic and not at all specific to the particular issue at Davis-Besse.

MR. WALLIS: Are they doing experiments in boiling boric acid?

MR. CULLEN: Yes. The temperature range

is from just what you said, from boiling solutions at various concentrations up to as high a temperature as we can get and whatever solution we can get in the autoclaves that are available, something around 600 and extremely concentrated is the answer.

We've encountered some experimental difficulties in elevated temperatures in more highly concentrated solutions, which is not surprising to me, but most of the work in boiling solutions has been completed.

MR. WALLIS: When the boric dissolves the steel, what form of chemical ferreting stuff comes off or whatever it is?

MR. CULLEN: A question that I can't answer. I'm not the kind of guru that gets into that kind of thing, but I do know from some steam generator related research there are lithium ion borates, the usual list of suspects and culprits that I think you'd expect when you corrode low alloy steel in boric acid solutions.

And some of them are very complex, and we may not have a full set of thermodynamic data for all of the compounds that are going to be formed, but there is some modeling of the environment that's going to go on here that's going to be completed.

I talked a little bit earlier on about the computational model and the inputs into that model, and I've talked quite extensively about the fact that we've harvested some of the alloys and that we're going to do some actual crack growth rate.

MR. WALLIS: When they took off the head and tried to, I think, bore it out and the thing fell over and all of that --

MR. CULLEN: Yeah.

MR. WALLIS: -- the material in the hole was solid?

MR. CULLEN: I've got other pictures. The hole was there. The hole was not full of something.

MR. WALLIS: It was not full?

MR. CULLEN: No, and presumably because whatever was there --

MR. WALLIS: Liquid would have evaporated, but solid would have perhaps stayed in.

MR. CULLEN: Yeah. Now, the cavity was crudded up, and that may be putting it lightly.

MR. WALLIS: Analyzing the crud might be very useful. I'm sure it's being done.

MR. CULLEN: The analysis of -- some of the crud was recovered.

MR. HISER: But before they realized

there was a hole, they cleaned the head, and then they said, "Oops, there's a hole," and yeah, there were some trace deposits that were found. I'm not sure that we've seen the analyses of those, the chem. analyses, but not much.

I mean, unfortunately, things got further away before they realized they had a problem.

MR. WALLIS: It was the first time they cleaned the head, wasn't it?

MR. CULLEN: I'm sorry?

PARTICIPANT: Until then they had never cleaned it?

MR. CULLEN: The licensee is going to deliver a final report to the agency somewhere in a month or so kind of time frame, as far as I know, and presumably all of that information is going to be in that report.

And we're also going to do the electrochemical potential and polarization measurements of these solutions against the materials that are relevant.

A couple of slides here now on the structural integrity assessment. Remember I said a few minutes ago that we needed to know the properties of the clad, the extent of the cracking in the clad in

order to revise and redo a structural integrity assessment that was underway.

That information has been provided to our contractor. We expect to get answers to this in a couple of months, but the approach is both analytic and experimental. A finite element model of the head containing the cavity and the exposed cladding.

There are two possible approaches, simple plastic -- well, I say "simple." Easy for me to say -- plastic instability model that's calibrated by some experimental data that already existed, and then also to take a look at whether those cracks would have extended in length by a ductile tearing process.

All of that is going to be a part of this deliverable which will arrive in a couple of --

MR. POWERS: Excuse me. Do I understand that you're doing this to say, "Okay. I got a quarter of an inch of this stainless steel cladding left. How much pressure can it tolerate to fail?"

MR. CULLEN: That is one of the two questions that we're trying to deliver to our colleagues doing the ASP. That's correct.

MR. POWERS: Okay, and could you tell me the second question before I ask my second question?

MR. CULLEN: The second question gets a

little more difficult to articulate, but part of the ASP process is to try to predict where this licensee, where the plant was a year ago. So we have to sort of back-calculate what we think the size of the cavity was.

MR. POWERS: And so you want to say, okay, what's the failure probability with the cladding plus a little bit of material.

MR. CULLEN: But in both cases --

MR. POWERS: Suppose that you find out that it's 8,000 psi.

MR. CULLEN: Okay.

MR. POWERS: Are you going to announce, oh, okay; everybody can go ahead and let their vessels corrode?

MR. ROSEN: They've got this really robust layer lying there.

MR. CULLEN: Of clad.

MR. POWERS: I mean suppose you get the answer to this question. What are you going to do with it?

MR. CULLEN: Well, you know, from a number like 8,000 psi, not that people are going to let their heads corrode or let the licensees get away with a lot of leakage or anything like that, but we would, I

think derive some better understanding of the overall robustness of the design of these plants.

And you know, it gives you a warm, fuzzy feeling. I don't want to say that we're sinking tens of thousands of dollars into trying to get a warm, fuzzy feeling, but it's a requirement for us to provide this data to this analysis, and we're doing that.

MR. KRESS: Are you going to ask the question how big that hole has to be before it fails?

MR. CULLEN: I'm not sure whether that's going to be part of this or not. I don't think so. It's not a requirement for us to project going forward.

MR. POWERS: Tom, even if I had that answer, I mean, what would I do with it? Say, "Okay. We can make these vessels out of Playdough or something"?

It seems like it's an answer to a question that I don't know how I'd utilize it.

MR. WALLIS: Well, the story would be more complete. It would make a much better story and a drama if you knew the answer to some of these things whether you're going to do anything with it or not.

MR. KRESS: But Dana is right. There's

nothing you would do with it in a regulatory sense.

MR. POWERS: Yeah. Am I going to tell them, okay, you know, go ahead and build them out of tin sheeting or something like that?

CO-CHAIRMAN SIEBER: There may be some public confidence aspect.

MR. POWERS: I'm pretty sure that the public reaction to you saying that the vessel wasn't going to fail is going to be loss of confidence in the NRC.

MR. KRESS: Maybe it's an input into the significance determination process.

MR. POWERS: You know, it seems to me that there's just no choice in this matter. You're going to have to say, "Look. The ASME code says build the damned thing this thick. You're going to build it that thick and keep it intact."

I don't care how thing the stuff gets. Don't let it get thin.

MR. WALLIS: I think when you're up there and some Senator asks you these questions you don't have an answer. Otherwise you might just --

MR. POWERS: No, the answer to these question is this was a bad thing. We don't like this to happen to our reactor heads.

MR. WALLIS: That doesn't sound very technically sophisticated.

MR. POWERS: I don't think I have to be very technically sophisticated to tell him this was a bad thing. He knows it from the face of it.

CO-CHAIRMAN FORD: Let's move on.

MR. POWERS: Okay, all right.

MR. CULLEN: Summarizing now, this structural integrity assessment has both an analytical aspect to it and an experimental aspect to it shown on the next slide. We are constructing a simplified, admittedly, model of the cavity with stainless steel that simulates the unbacked cladding, and I can't remember exactly how many of these models are going to be constructed, but several is definitely the answer.

MR. POWERS: Let me ask you a question. You say it simulates the unbacked cladding. I mean, how in the world do you do that?

MR. CULLEN: Does somebody here know the answer to that? I'm not the PM for that particular program.

PARTICIPANT: (Unintelligible), NRC.

We are using cutout from the vessel cladding, and so the disks have been cut out, and then they will be in this chamber. This is the pressurizer

chamber.

MR. POWERS: So it's not simulating the cladding. It is the cladding.

PARTICIPANT: It is the cladding.

MR. ROSEN: Is it from P.D. Ruff (phonetic) or Midland or --

PARTICIPANT: P.D. Ruff.

MR. WALLIS: You're going to boil boric acid in the hole?

MR. CULLEN: No, I don't think that's the point of this particular program.

MR. KRESS: Pressurize it at temperature?

MR. CULLEN: Yeah, just pressurize it and find out when it's going to blow out.

MR. WALLIS: -- experiments where you boil boric acid in holes and see how fast the hole grows?

MR. CULLEN: No.

MR. KRESS: This is to validate your pressure.

MR. CULLEN: Yeah, right. It's the validate the calculational model with these sorts of admittedly simplified experiments, but --

MR. POWERS: You mean there are calculational models on what happens to a -- it amounts to a rupture disk problem here -- are so bad

that we have to do a whole suite of calculations?

MR. CULLEN: Well, I mean, you say "rupture disk," and you know, that was my first impression, too, is, my gosh, these guys have been making rupture disks for years. The equations have to exist.

But you know, the similitude is not that perfect. The cladding is more thick in a proportional way than you would get in a rupture disk.

MR. POWERS: That's right.

MR. CULLEN: The disk cladding had flaws in it. That's the point I want to get to.

MR. POWERS: That's right. You're going to find out how many flaws you have in this cladding. If you do any one particular one of these tests you'll get a pressure. Now, repeat exactly that same -- you're going to end up with another one of your plots with data all over the place.

MR. CULLEN: Possibly.

MR. POWERS: I mean it's all going to be because of little flaws that you haven't characterized.

MR. WALLIS: So we need 59 experiments.

MR. POWERS: To create a plot we can't use.

MR. ROSEN: Mr. Chairman.

MR. WALLIS: I think we should move on, yes.

CO-CHAIRMAN FORD: Yes.

MR. CULLEN: But at any rate, we are going to pressurize and measure the bursting pressure on this unbacked cladding that is not flawed, that is flawed, flawed in various geometries so that we kind of get a spectrum of the performance of the simulated cavities that look like that.

Okay. These things are coming in kind of one by one here.

MR. WALLIS: Now you said you were duplicating the EPRI work. Are they doing the same thing?

MR. CULLEN: No, I don't think EPRI is doing anything like this. I was sort of whining about that with respect to the boric acid corrosion program.

Now, this is something that we're doing on our own initiative, and again, principally as input to the ASP.

CO-CHAIRMAN FORD: Okay. Good.

MR. CULLEN: Okay. One last thing here now just to review a little bit and point out again what's happening going forward. The licensee has

taken a look at Nozzle No. 3 and you've seen a summary of that sort of work. Very soon the Nozzle Nos. 2 and 46 are going to be removed from the Davis-Besse head and to be sent a couple of different places for different types of examinations.

One last time we're doing crack growth rate testing on the alloys that came out of the Davis-Besse head, and as you heard this morning, the North Anna Unit 2 head is being harvested by the industry and hopefully will have some coordination of the research and the failure analysis that will be done on that thing.

And with that, I finally made it through.

CO-CHAIRMAN FORD: Thank you very much, and you're just in time to get your flight.

MR. CULLEN: Yeah.

CO-CHAIRMAN FORD: Any questions for Bill?

(No response.)

CO-CHAIRMAN FORD: Thank you very much, indeed. I appreciate it.

I was told earlier on that for the full committee meeting that the MRP or industry will not be present because of prior -- am I correct? -- because of prior engagements. Therefore, the presentations will be primarily restricted to the NRC regulators and

research.

So when you're thinking about what advice we're going to give, bear in mind they will only be there.

Do I have a motion to retire for the night?

MR. KRESS: You do.

MR. POWERS: You can do it in a high handed, cavalier fashion.

MR. KRESS: You have absolutely power to do this.

CO-CHAIRMAN FORD: We will recess until tomorrow morning at 8:30.

(Whereupon, at 4:50 p.m., the meeting was adjourned, to reconvene at 8:30 a.m., Wednesday, April 23, 2003.)