

1 MR. ALLEY: EPRI does this for us.

2 MR. POWERS: Oh, okay.

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

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

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

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

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

22 MR. POWERS: It might make them look  
23 realistic.

24 MR. ALLEY: That would be debatable.

25 Okay. The next slide is going to show the

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

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

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

15 MR. ROSEN: So that's fairly clever.

16 MR. ALLEY: We have our moments.

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

19 MR. ALLEY: Yeah.

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

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

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

4 The next slide just shows the close-up.

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

7 MR. ALLEY: Yeah, but the --

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

10 MR. ALLEY: This is an eddy current.

11 CO-CHAIRMAN SIEBER: An eddy current.

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

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

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

24 MR. MATHEWS: It's pretty rough.

25 MR. ALLEY: It's pretty rough actually.

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

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

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

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

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

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

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

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

7 MR. WALLIS: Is the resolution limit.

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

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

13 MR. POWERS: How is the probe coupled?

14 MR. ALLEY: It's just water.

15 MR. POWERS: You immerse --

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

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

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

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

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

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

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

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

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

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

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

19           CO-CHAIRMAN FORD: That's right.

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

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1 MR. ALLEY: So we saw on Vendor A the  
2 blade probe performance, the open tube. Rotating  
3 probe performance, again, was a little better, 13  
4 percent to 100 percent, again with the ideal  
5 orientation, and with the non-ideal orientation we had  
6 15 to 100 percent.

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

11 Vendor B, we see the same numbers, 15 to  
12 100 percent for blade probe and 15 to 100 percent for  
13 the non-optimum orientation blade probe. Open tube,  
14 we see down to ten percent here for this particular  
15 vendor, perform perhaps a little better, although  
16 we're starting to get, you know -- the five percent is  
17 starting to get kind of in the grass.

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

20 MR. ALLEY: The through wall extent.

21 MR. ROSEN: Extent.

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

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1 with the tube scanner.

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

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

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

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

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1 circumferential flaw.

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

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

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

16 Vendor C looked at blade probe UT as well,  
17 16 percent to 100 percent, 18 to 100 percent. The  
18 open tube scanner was 13 to 100 and flaws ranged from  
19 15 to 100 with the open tube scanner that are oriented  
20 parallel to the beam direction.

21 Again, we're seeing a lot of consistency  
22 in these numbers. They are from ten to 15 percent to  
23 100 percent through wall for all of these vendors.  
24 Now, what that means to me personally is we're  
25 starting to push that technique about as far as we can

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

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

10 MR. ALLEY: It's not very challenging?

11 MR. POWERS: Yeah.

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

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

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

25 And I think that's telling us that with

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

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

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

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

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

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

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

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

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

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

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1 that conclusion.

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

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

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

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

25 So there's this constant swap in eddy

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

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

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

16 CO-CHAIRMAN FORD: Okay.

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

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

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

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

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

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

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

25 So they're both working on the deployment

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1 of that.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

13 And that concludes the comments I have for  
14 you.

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

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

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

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1                   When do we get a report card or how do we  
2 go about getting a report card that says, "Gee, these  
3 guys inspected all of these locations and they got  
4 99.3 percent of all the cracks"?

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

23 (No response.)

24 CO-CHAIRMAN FORD: Okay. Alex.

25 Thank you very much.

1 MR. MARION: Thank you.

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

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

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

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

25 Last summer as a result of the Davis-Besse

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

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

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

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

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

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

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

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

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

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

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

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

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

16 MR. MARION: Thank you.

17 CO-CHAIRMAN FORD: Any questions?

18 (No response.)

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

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

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

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1 and we've got everything else.

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

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

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

11 MR. CULLEN: Something like that must have  
12 happened.

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

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

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

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1 by that.

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

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

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

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

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

11 Also, just as a little bit of an  
12 advertisement, I'm going to talk up here about some  
13 LLTF, lessons learned task force, issues that they  
14 raised about stress corrosion cracking in the Alloy  
15 600 and then the boric acid corrosion issue. But down  
16 here -- and you'll hear about both of these things in  
17 a much more detail tomorrow. One of my colleagues,  
18 Danny Santos will be talking specifically tomorrow  
19 about the LLTF recommendations on the barrier  
20 integrity or on leakage, and that's another issue that  
21 was raised somewhat extensively this morning and I  
22 think will be a good deal talked about tomorrow on the  
23 leakage issue and what those recommendations mean and  
24 what we might be led to in that particular area.

25 Okay.

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

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

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

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

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

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

25 In order to do that sort of calculation,

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

21 MR. POWERS: Maybe that's the document.

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

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

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1 it has to be this good.

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

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

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

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

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

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

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

22              I can see a question coming.

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

25              MR. CULLEN: Go for it.

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

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

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

12 MR. POWERS: They got religion over this  
13 subject.

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

18 Does anybody have any idea? Keith?

19 PARTICIPANT: Germans' use of steam  
20 generators.

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

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

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

5 MR. CULLEN: It certainly --

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

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

11 MR. POWERS: I was just curious.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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1 stress corrosion cracking determination on these  
2 particular materials.

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

7 MR. CULLEN: Starts, shutdowns, standbys.

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

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

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

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

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

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

5 MR. CULLEN: That's correct.

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

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

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

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

20 CO-CHAIRMAN FORD: The worst case  
21 scenario.

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

25 CO-CHAIRMAN FORD: The other question I

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

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

8 CO-CHAIRMAN FORD: Evaluating?

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

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

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

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

20 CO-CHAIRMAN FORD: Fantastic.

21 MR. HISER: How does that sound?

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

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

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

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

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

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

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

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

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

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

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

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

23           CO-CHAIRMAN FORD: Okay.

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

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

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

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

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

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

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

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1 some of the results from Alloy 182.

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

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

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

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

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

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1 worldwide. So we participate in the meetings.

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

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

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

9 MR. POWERS: That's good.

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

14 Phase 2, which is the one that we're in  
15 right now is to test a 30 percent cold-worked Alloy  
16 600, then compare those results and prove the methods  
17 and do a follow-on test. Thirty percent cold-worked  
18 Alloy 600 should crack fairly expeditiously, shall we  
19 say? The test should last about a month or so, given  
20 what the specific test parameters are. It should not  
21 be an impossible onus on any laboratory.

22 In Phase 3, we will go on and test Alloy  
23 182. So we will get a good deal of data on both Alloy  
24 600 and Alloy 182 out of this particular round robin  
25 experience.

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

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

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

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

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

25 Okay. I'd like to take two slides and

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

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

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

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

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

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

3 Now, as we just learned this morning,  
4 North Anna 1 is also replacing its head, as is Surry  
5 2, but these other plants, Sequoia 1 and 2, Watts Bar,  
6 Catawba, McGuire, don't have any immediate plans. I  
7 think Sequoia has got a long term, maybe 2006 plan.

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

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

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

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

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

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

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

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

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1 United States during that particular time period.

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

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

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

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

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

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

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

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

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

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

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

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

25 MR. CULLEN: I think the answer from an

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

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

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

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

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

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

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

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

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

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

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

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

13 MR. POWERS: Oh.

14 MR. CULLEN: Okay?

15 MR. POWERS: On a PC.

16 MR. CULLEN: Well, yeah.

17 MR. POWERS: Oh.

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

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

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

25 So that's where we are with these

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1 calculations these days.

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

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

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

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

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

6 The last slide in this series is that if  
7 you compute both the axial, the circumferential, and  
8 the radial stresses, it turns out that the resolution  
9 of these stresses is on an inclined plane. I'm kind  
10 of waving the laser here in parallel with the arrows,  
11 which I presume are visible to you more in front of  
12 the screen. But what this says since a crack tends to  
13 grow normal to the principle stresses is that cracks  
14 should grow perhaps somewhat along -- these would be  
15 a circumferential crack now -- perhaps along about a  
16 45 degree incline plane.

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

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

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

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

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

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

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

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

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

24           MR. ROSEN:   Yeah, temperature.

25           MR. CULLEN:   You know, through the

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

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

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

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

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

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

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

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

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

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

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

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

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1 Boy, they're lining up back there now.

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

6 MR. MATHEWS: This is Larry Mathews.

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

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

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

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

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

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

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

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

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

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

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

5 MR. SIMS: Going back to the statement  
6 about stresses though and proving it in the industry -  
7 -

8 PARTICIPANT: You have to identify  
9 yourself.

10 MR. SIMS: William Sims, Entergy  
11 Operations.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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1 thickness of steam generator tubes also has huge  
2 spreads.

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

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

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

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

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

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

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

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

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

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

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1 haven't yet quite figured out.

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

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

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

9 CO-CHAIRMAN FORD: Okay.

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

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

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

15 (Laughter.)

16 MR. POWERS: I'm sitting here waiting.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

25 Does that response reasonably satisfy your

1 concern?

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

4 MR. CULLEN: Okay.

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

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

11 MR. CULLEN: Absolutely.

12 MR. POWERS: It absolutely has to be  
13 independent.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

22 MR. CULLEN: I mean, that is --

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

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

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

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

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

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

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

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

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

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

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

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1 these corrosion cavities get started.

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

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

6 MR. CULLEN: Let's do it.

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

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

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

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

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

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

25 It's nobody's objective to fit a line

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

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

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

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

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

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

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

18 MR. CULLEN: Just a list.

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

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

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

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

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

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

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

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

24 MR. CULLEN: -- that you were thinking of.  
25 You know, they all fall into the general

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

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

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

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

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

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

25 MR. POWERS: Somehow a regression analysis

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1 is not a triumph --

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

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

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

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

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

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

6 (Laughter.)

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

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

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

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

25 CO-CHAIRMAN FORD: Let me try and help.

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

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

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

8 MR. CULLEN: But it's one technique.

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

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

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

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

25 MR. WALLIS: The variable to quantify.

1 CO-CHAIRMAN SIEBER: That's one factor.

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

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

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

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

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

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

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

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

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

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

16 MR. POWERS: Thirty-five.

17 MR. CULLEN: Yeah.

18 MR. WALLIS: Oh, the middle.

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

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

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

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

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

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

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

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

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

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

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

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1 like that.

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

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

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

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

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

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

22 MR. CULLEN: That is a possibility.

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

25 MR. CULLEN: You are correct.

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1 MR. WALLIS: You have your inspection  
2 intervals accordingly.

3 MR. CULLEN: Again, correct.

4 MR. WALLIS: Forget about everything else.

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

8 MR. WALLIS: As you learn.

9 MR. KRESS: As you go along and learn.

10 MR. WALLIS: Yes.

11 MR. KRESS: I agree.

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

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

20 CO-CHAIRMAN SIEBER: It might get worse?  
21 (Laughter.)

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

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

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1       come down?

2                   MR. ROSEN:   That's right.

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

5                   MR. ROSEN:   Artificial neural network.

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

8                   CO-CHAIRMAN FORD:  Thanks, Bob.

9                   PARTICIPANT:  That means no more problems  
10      here.

11                   (Laughter.)

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

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

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

1 MR. POWERS: For something called T sub F.

2 MR. MATHEWS: Time to failure.

3 MR. CULLEN: Time to failure.

4 MR. POWERS: You are bright.

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

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

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

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

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

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

25 There are things that we know well. I

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

4 MR. WALLIS: About leakage through cracks?

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

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

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

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

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

25 MR. KRESS: Do you fix it the next

1 shutdown?

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

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

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

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

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

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

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

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

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1 MR. ROSEN: Except for the steam generator  
2 tubes.

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

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

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

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

15 CO-CHAIRMAN SIEBER: Well --

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

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

21 MR. POWERS: You have flaw evaluation  
22 guidelines.

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

25 CO-CHAIRMAN SIEBER: The only way you're

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

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

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

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

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

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

19 (Laughter.)

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

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

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

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

8 CO-CHAIRMAN FORD: Okay.

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

11 (Laughter.)

12 MR. CULLEN: Okay. Let's --

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

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

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

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

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

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

10 MR. WALLIS: What does plant ranking mean  
11 here?

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

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

17 MR. CULLEN: And it is.

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

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

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

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

5                   MR. CULLEN:    Yeah, that's true.

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

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

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

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

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

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

25                   MR. CULLEN:    Yep.

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

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

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

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

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

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

23 CO-CHAIRMAN FORD: Okay.

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

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

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

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

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

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

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

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

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

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

25 They took a look at the cracks in the

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

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

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

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

25 There's another very large crack, actually

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

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

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

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

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

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

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

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

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

25 MR. WALLIS: Oh, through the head.

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

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

8 MR. CULLEN: One, point, two inches versus  
9 1.1.

10 MR. SHACK: Was it through wall?

11 MR. CULLEN: Yes.

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

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

16 PARTICIPANT: Non-eroding at any rate.

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

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

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

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

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

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

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

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

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

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

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

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

17 MR. CULLEN: Okay.

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

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

1 thick right here at this little tucked in corner.

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

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

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

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

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

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

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

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

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

24 MR. POWERS: Elicited a lot of comment.z

25 MR. ROSEN: Earth shattering, curious.

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

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

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

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

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

10 MR. WALLIS: Yes.

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

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

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

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

1 right?

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

6 MR. ROSEN: Looks like a crack to me.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

21 MR. CULLEN: Yeah.

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

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

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

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

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

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

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

18 MR. CULLEN: On a highly, highly --

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

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

24 MR. WALLIS: Oh, they don't?

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

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

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

6 MR. CULLEN: That's correct.

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

9 MR. CULLEN: That's correct.

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

12 MR. CULLEN: That is --

13 MR. WALLIS: How can you use a K?

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

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

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

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

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

25 Okay. If you open this crack up, this is

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

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

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

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

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

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

20 MR. WALLIS: Nothing else looks like that?

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

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

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1 crack.

2 MR. CULLEN: Yeah.

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

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

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

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

19 MR. WALLIS: That's some tip.

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

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

25 Is that a tight crack to you?

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

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

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

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

18 And remember this is just a slice.

19 MR. POWERS: I understand.

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

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

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

1           openness in the crack enclave.

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

5                   MR. CULLEN:    That's correct.

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

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

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

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

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

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

25                   MR. WALLIS:   I know.

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

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

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

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

12 MR. ROSEN: Yeah, there are lots.

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

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

22 MR. CULLEN: Yeah.

23 MR. WALLIS: You change what's there.

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

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

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

5 MR. CULLEN: Presumably.

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

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

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

12 MR. CULLEN: Stress.

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

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

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

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

24 Going now to the clad --

25 MR. WALLIS: That was wonderful.

1 MR. CULLEN: I'm sorry?

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

4 MR. CULLEN: I still didn't hear.

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

7 MR. CULLEN: Oh, okay.

8 MR. WALLIS: Remarkable.

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

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

25 And these cracks, if you open them up as

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

4 MR. WALLIS: Well, why do you say it was  
5 212? Doesn't the boiling point go up on --

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

7 MR. WALLIS: It goes up quite a lot.

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

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

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

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

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

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

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

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

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

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

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

1 MR. WALLIS: Just include these cracks in  
2 that.

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

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

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

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

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1 it is, very frankly, a dilemma

2 MR. ROSEN: Because there's a bulge.

3 MR. CULLEN: Because there's a bulge.

4 Now, that bulge, it was not a case of the cracks  
5 growing and then the bulging because we would see  
6 rounded crack tips.

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

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

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

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

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

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

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1 of that.

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

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

10 MR. CULLEN: Yes.

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

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

16 CO-CHAIRMAN FORD: Okay.

17 MR. CULLEN: There is a message about  
18 that.

19 CO-CHAIRMAN FORD: Okay.

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

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

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

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

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

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

15 MR. WALLIS: Shut down the reactor.

16 MR. ROSEN: That could be.

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

22 MR. WALLIS: They should be longer.

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

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

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

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

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

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

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

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1                   Lots more questions than we have answers  
2 right now.

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

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

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

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

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

22                   MR. CULLEN: Don't know.

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

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

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

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

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

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

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

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

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

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

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

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

6 MR. CULLEN: Yes.

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

10 MR. CULLEN: That's absolutely correct.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

5 MR. CULLEN: Well, you know, my experience  
6 in similar environment -- I won't say exactly similar  
7 environments -- but concentrated acid, concentrated  
8 sulfate environments of low alloy steel is that these  
9 sorts of dimples usually develop where you have an  
10 inclusion that acts as a local corrosion accelerant.

11 So, yeah, they are related to the micro  
12 structure. The point that the licensee is going to  
13 make is that these depressions are related to this  
14 layering, this segregation, banding, whatever you'd  
15 like to call it. You can see this cutout right here  
16 is kind of related to these bands. This here is  
17 related to that black band. You have another --

18 MR. WALLIS: This looks more geological  
19 all the time.

20 MR. CULLEN: Oh, yeah, yeah. But you  
21 know, this banding is related to the inclusion content  
22 in the alloy and does provide what I think is a  
23 reasonable rationale for why you get the highly  
24 textured surface, the voiding.

25 MR. WALLIS: Well, you've almost got the

1 old man of the mountains up there.

2 MR. CULLEN: Yeah, yeah. You can let your  
3 mind run in a lot of directions on some of those  
4 profiles.

5 Okay. So talking a little bit now about  
6 the specific program that we've got in place out at  
7 Argonne, I want to stress that although we started  
8 this program as a result of finding this massive  
9 corrosion at Davis-Besse and as a consequence of the  
10 fact that I really couldn't find data that we needed  
11 to have to help with the dispositioning and the  
12 understanding of that right at the beginning, we  
13 developed this program at Argonne.

14 There is a lot of work on the generic  
15 description of corrosion of pressure boundary alloys  
16 and concentrated boric acid solutions, low alloy  
17 steel, Alloy 600 and 182. I think we've going to try  
18 to get some 308 in here as well.

19 So even though the program was spurred on,  
20 if you will, by the findings at Davis-Besse, we've  
21 designed this program to be very generic and not at  
22 all specific to the particular issue at Davis-Besse.

23 MR. WALLIS: Are they doing experiments in  
24 boiling boric acid?

25 MR. CULLEN: Yes. The temperature range

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1 is from just what you said, from boiling solutions at  
2 various concentrations up to as high a temperature as  
3 we can get and whatever solution we can get in the  
4 autoclaves that are available, something around 600  
5 and extremely concentrated is the answer.

6 We've encountered some experimental  
7 difficulties in elevated temperatures in more highly  
8 concentrated solutions, which is not surprising to me,  
9 but most of the work in boiling solutions has been  
10 completed.

11 MR. WALLIS: When the boric dissolves the  
12 steel, what form of chemical ferreting stuff comes off  
13 or whatever it is?

14 MR. CULLEN: A question that I can't  
15 answer. I'm not the kind of guru that gets into that  
16 kind of thing, but I do know from some steam generator  
17 related research there are lithium ion borates, the  
18 usual list of suspects and culprits that I think you'd  
19 expect when you corrode low alloy steel in boric acid  
20 solutions.

21 And some of them are very complex, and we  
22 may not have a full set of thermodynamic data for all  
23 of the compounds that are going to be formed, but  
24 there is some modeling of the environment that's going  
25 to go on here that's going to be completed.

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1 I talked a little bit earlier on about the  
2 computational model and the inputs into that model,  
3 and I've talked quite extensively about the fact that  
4 we've harvested some of the alloys and that we're  
5 going to do some actual crack growth rate.

6 MR. WALLIS: When they took off the head  
7 and tried to, I think, bore it out and the thing fell  
8 over and all of that --

9 MR. CULLEN: Yeah.

10 MR. WALLIS: -- the material in the hole  
11 was solid?

12 MR. CULLEN: I've got other pictures. The  
13 hole was there. The hole was not full of something.

14 MR. WALLIS: It was not full?

15 MR. CULLEN: No, and presumably because  
16 whatever was there --

17 MR. WALLIS: Liquid would have evaporated,  
18 but solid would have perhaps stayed in.

19 MR. CULLEN: Yeah. Now, the cavity was  
20 crudded up, and that may be putting it lightly.

21 MR. WALLIS: Analyzing the crud might be  
22 very useful. I'm sure it's being done.

23 MR. CULLEN: The analysis of -- some of  
24 the crud was recovered.

25 MR. HISER: But before they realized

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1 there was a hole, they cleaned the head, and then they  
2 said, "Oops, there's a hole," and yeah, there were  
3 some trace deposits that were found. I'm not sure  
4 that we've seen the analyses of those, the chem.  
5 analyses, but not much.

6 I mean, unfortunately, things got further  
7 away before they realized they had a problem.

8 MR. WALLIS: It was the first time they  
9 cleaned the head, wasn't it?

10 MR. CULLEN: I'm sorry?

11 PARTICIPANT: Until then they had never  
12 cleaned it?

13 MR. CULLEN: The licensee is going to  
14 deliver a final report to the agency somewhere in a  
15 month or so kind of time frame, as far as I know, and  
16 presumably all of that information is going to be in  
17 that report.

18 And we're also going to do the  
19 electrochemical potential and polarization  
20 measurements of these solutions against the materials  
21 that are relevant.

22 A couple of slides here now on the  
23 structural integrity assessment. Remember I said a  
24 few minutes ago that we needed to know the properties  
25 of the clad, the extent of the cracking in the clad in

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1 order to revise and redo a structural integrity  
2 assessment that was underway.

3 That information has been provided to our  
4 contractor. We expect to get answers to this in a  
5 couple of months, but the approach is both analytic  
6 and experimental. A finite element model of the head  
7 containing the cavity and the exposed cladding.

8 There are two possible approaches, simple  
9 plastic -- well, I say "simple." Easy for me to  
10 say -- plastic instability model that's calibrated by  
11 some experimental data that already existed, and then  
12 also to take a look at whether those cracks would have  
13 extended in length by a ductile tearing process.

14 All of that is going to be a part of this  
15 deliverable which will arrive in a couple of --

16 MR. POWERS: Excuse me. Do I understand  
17 that you're doing this to say, "Okay. I got a quarter  
18 of an inch of this stainless steel cladding left. How  
19 much pressure can it tolerate to fail?"

20 MR. CULLEN: That is one of the two  
21 questions that we're trying to deliver to our  
22 colleagues doing the ASP. That's correct.

23 MR. POWERS: Okay, and could you tell me  
24 the second question before I ask my second question?

25 MR. CULLEN: The second question gets a

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1 little more difficult to articulate, but part of the  
2 ASP process is to try to predict where this licensee,  
3 where the plant was a year ago. So we have to sort of  
4 back-calculate what we think the size of the cavity  
5 was.

6 MR. POWERS: And so you want to say, okay,  
7 what's the failure probability with the cladding plus  
8 a little bit of material.

9 MR. CULLEN: But in both cases --

10 MR. POWERS: Suppose that you find out  
11 that it's 8,000 psi.

12 MR. CULLEN: Okay.

13 MR. POWERS: Are you going to announce,  
14 oh, okay; everybody can go ahead and let their vessels  
15 corrode?

16 MR. ROSEN: They've got this really robust  
17 layer lying there.

18 MR. CULLEN: Of clad.

19 MR. POWERS: I mean suppose you get the  
20 answer to this question. What are you going to do  
21 with it?

22 MR. CULLEN: Well, you know, from a number  
23 like 8,000 psi, not that people are going to let their  
24 heads corrode or let the licensees get away with a lot  
25 of leakage or anything like that, but we would, I

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1 think derive some better understanding of the overall  
2 robustness of the design of these plants.

3 And you know, it gives you a warm, fuzzy  
4 feeling. I don't want to say that we're sinking tens  
5 of thousands of dollars into trying to get a warm,  
6 fuzzy feeling, but it's a requirement for us to  
7 provide this data to this analysis, and we're doing  
8 that.

9 MR. KRESS: Are you going to ask the  
10 question how big that hole has to be before it fails?

11 MR. CULLEN: I'm not sure whether that's  
12 going to be part of this or not. I don't think so.  
13 It's not a requirement for us to project going  
14 forward.

15 MR. POWERS: Tom, even if I had that  
16 answer, I mean, what would I do with it? Say, "Okay.  
17 We can make these vessels out of Playdough or  
18 something"?

19 It seems like it's an answer to a question  
20 that I don't know how I'd utilize it.

21 MR. WALLIS: Well, the story would be more  
22 complete. It would make a much better story and a  
23 drama if you knew the answer to some of these things  
24 whether you're going to do anything with it or not.

25 MR. KRESS: But Dana is right. There's

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1 nothing you would do with it in a regulatory sense.

2 MR. POWERS: Yeah. Am I going to tell  
3 them, okay, you know, go ahead and build them out of  
4 tin sheeting or something like that?

5 CO-CHAIRMAN SIEBER: There may be some  
6 public confidence aspect.

7 MR. POWERS: I'm pretty sure that the  
8 public reaction to you saying that the vessel wasn't  
9 going to fail is going to be loss of confidence in the  
10 NRC.

11 MR. KRESS: Maybe it's an input into the  
12 significance determination process.

13 MR. POWERS: You know, it seems to me that  
14 there's just no choice in this matter. You're going  
15 to have to say, "Look. The ASME code says build the  
16 damned thing this thick. You're going to build it  
17 that thick and keep it intact."

18 I don't care how thing the stuff gets.  
19 Don't let it get thin.

20 MR. WALLIS: I think when you're up there  
21 and some Senator asks you these questions you don't  
22 have an answer. Otherwise you might just --

23 MR. POWERS: No, the answer to these  
24 question is this was a bad thing. We don't like this  
25 to happen to our reactor heads.

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1 MR. WALLIS: That doesn't sound very  
2 technically sophisticated.

3 MR. POWERS: I don't think I have to be  
4 very technically sophisticated to tell him this was a  
5 bad thing. He knows it from the face of it.

6 CO-CHAIRMAN FORD: Let's move on.

7 MR. POWERS: Okay, all right.

8 MR. CULLEN: Summarizing now, this  
9 structural integrity assessment has both an analytical  
10 aspect to it and an experimental aspect to it shown on  
11 the next slide. We are constructing a simplified,  
12 admittedly, model of the cavity with stainless steel  
13 that simulates the unbacked cladding, and I can't  
14 remember exactly how many of these models are going to  
15 be constructed, but several is definitely the answer.

16 MR. POWERS: Let me ask you a question.  
17 You say it simulates the unbacked cladding. I mean,  
18 how in the world do you do that?

19 MR. CULLEN: Does somebody here know the  
20 answer to that? I'm not the PM for that particular  
21 program.

22 PARTICIPANT: (Unintelligible), NRC.

23 We are using cutout from the vessel  
24 cladding, and so the disks have been cut out, and then  
25 they will be in this chamber. This is the pressurizer

1 chamber.

2 MR. POWERS: So it's not simulating the  
3 cladding. It is the cladding.

4 PARTICIPANT: It is the cladding.

5 MR. ROSEN: Is it from P.D. Ruff  
6 (phonetic) or Midland or --

7 PARTICIPANT: P.D. Ruff.

8 MR. WALLIS: You're going to boil boric  
9 acid in the hole?

10 MR. CULLEN: No, I don't think that's the  
11 point of this particular program.

12 MR. KRESS: Pressurize it at temperature?

13 MR. CULLEN: Yeah, just pressurize it and  
14 find out when it's going to blow out.

15 MR. WALLIS: -- experiments where you boil  
16 boric acid in holes and see how fast the hole grows?

17 MR. CULLEN: No.

18 MR. KRESS: This is to validate your  
19 pressure.

20 MR. CULLEN: Yeah, right. It's the  
21 validate the calculational model with these sorts of  
22 admittedly simplified experiments, but --

23 MR. POWERS: You mean there are  
24 calculational models on what happens to a -- it  
25 amounts to a rupture disk problem here -- are so bad

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1 that we have to do a whole suite of calculations?

2 MR. CULLEN: Well, I mean, you say  
3 "rupture disk," and you know, that was my first  
4 impression, too, is, my gosh, these guys have been  
5 making rupture disks for years. The equations have to  
6 exist.

7 But you know, the similitude is not that  
8 perfect. The cladding is more thick in a proportional  
9 way than you would get in a rupture disk.

10 MR. POWERS: That's right.

11 MR. CULLEN: The disk cladding had flaws  
12 in it. That's the point I want to get to.

13 MR. POWERS: That's right. You're going  
14 to find out how many flaws you have in this cladding.  
15 If you do any one particular one of these tests you'll  
16 get a pressure. Now, repeat exactly that same --  
17 you're going to end up with another one of your plots  
18 with data all over the place.

19 MR. CULLEN: Possibly.

20 MR. POWERS: I mean it's all going to be  
21 because of little flaws that you haven't  
22 characterized.

23 MR. WALLIS: So we need 59 experiments.

24 MR. POWERS: To create a plot we can't  
25 use.

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1 MR. ROSEN: Mr. Chairman.

2 MR. WALLIS: I think we should move on,  
3 yes.

4 CO-CHAIRMAN FORD: Yes.

5 MR. CULLEN: But at any rate, we are going  
6 to pressurize and measure the bursting pressure on  
7 this unbacked cladding that is not flawed, that is  
8 flawed, flawed in various geometries so that we kind  
9 of get a spectrum of the performance of the simulated  
10 cavities that look like that.

11 Okay. These things are coming in kind of  
12 one by one here.

13 MR. WALLIS: Now you said you were  
14 duplicating the EPRI work. Are they doing the same  
15 thing?

16 MR. CULLEN: No, I don't think EPRI is  
17 doing anything like this. I was sort of whining about  
18 that with respect to the boric acid corrosion program.

19 Now, this is something that we're doing on  
20 our own initiative, and again, principally as input to  
21 the ASP.

22 CO-CHAIRMAN FORD: Okay. Good.

23 MR. CULLEN: Okay. One last thing here  
24 now just to review a little bit and point out again  
25 what's happening going forward. The licensee has

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1 taken a look at Nozzle No. 3 and you've seen a summary  
2 of that sort of work. Very soon the Nozzle Nos. 2 and  
3 46 are going to be removed from the Davis-Besse head  
4 and to be sent a couple of different places for  
5 different types of examinations.

6 One last time we're doing crack growth  
7 rate testing on the alloys that came out of the Davis-  
8 Besse head, and as you heard this morning, the North  
9 Anna Unit 2 head is being harvested by the industry  
10 and hopefully will have some coordination of the  
11 research and the failure analysis that will be done on  
12 that thing.

13 And with that, I finally made it through.

14 CO-CHAIRMAN FORD: Thank you very much,  
15 and you're just in time to get your flight.

16 MR. CULLEN: Yeah.

17 CO-CHAIRMAN FORD: Any questions for Bill?

18 (No response.)

19 CO-CHAIRMAN FORD: Thank you very much,  
20 indeed. I appreciate it.

21 I was told earlier on that for the full  
22 committee meeting that the MRP or industry will not be  
23 present because of prior -- am I correct? -- because  
24 of prior engagements. Therefore, the presentations  
25 will be primarily restricted to the NRC regulators and

1 research.

2 So when you're thinking about what advice  
3 we're going to give, bear in mind they will only be  
4 there.

5 Do I have a motion to retire for the  
6 night?

7 MR. KRESS: You do.

8 MR. POWERS: You can do it in a high  
9 handed, cavalier fashion.

10 MR. KRESS: You have absolutely power to  
11 do this.

12 CO-CHAIRMAN FORD: We will recess until  
13 tomorrow morning at 8:30.

14 (Whereupon, at 4:50 p.m., the meeting was  
15 adjourned, to reconvene at 8:30 a.m., Wednesday, April  
16 23, 2003.)

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