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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

OCTOBER 13, 2000

The contents of this transcript of the proceeding of the United States Nuclear Regulatory Commission Advisory Committee on Reactor Safeguards, taken on October 13, 2000, as reported herein, is a record of the discussions recorded at the meeting held on the above date.

This transcript has not been reviewed, corrected and edited and it may contain inaccuracies.

1 UNITED STATES

2 NUCLEAR REGULATORY COMMISSION

3 ***

4 ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

5 ***

6 AD HOC SUBCOMMITTEE ON DIFFERING

7 PROFESSIONAL OPINION ISSUES

8 ***

9 Friday, October 13, 2000

10 U.S. NRC

11 11545 Rockville Pike, Room T2-B3

12 Rockville, Maryland

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14 The above-entitled meeting commenced, pursuant to

15 notice, at 8:30 a.m.

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1 PARTICIPANTS:
2 Dana Powers, Chairman, ACRS
3 Mario Bonaca, ACRS Member
4 John (Jack) Sieber, ACRS Member
5 Thomas Kress, ACRS Member
6 Ivan Catton, Consultant
7 James Higgins, Consultant
8 Ronald Ballinger, Consultant
9 Jack Strosnider, Division of Engineering, NRR
10 Jack Hayes, Probabilistic Safety and Assessment Branch, NRR
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1 P R O C E E D I N G S

2 CHAIRMAN POWERS: The meeting will now come to
3 order.

4 This is the fourth day of the meeting of the ad
5 hoc ACRS Subcommittee on Differing Professional Opinion
6 issues. The purpose of the meeting is for the subcommittee
7 to review technical issues contained in the differing
8 professional opinion on steam generator tube integrity.

9 The subcommittee will continue to hear from the
10 NRC Staff today. In particular, we will continue our
11 discussions of damage propagation, then we'll hear specific
12 discussions on design basis accidents, severe accidents and
13 integrated decision-making.

14 The meeting is being conducted in accordance with
15 the provisions of the Federal Advisory Committee Act. Mr.
16 Sam Duraiswamy is the Designated Federal Official for this
17 meeting. Ms. Undine Shoop will be around someplace to
18 assist us.

19 We have received no written comments or requests
20 for time to make oral statements from members of the public.

21 A transcript of the meeting is being kept and it
22 is requested that speakers use one of the microphones,
23 identify themselves and speak with sufficient clarity and
24 volume so they can be readily heard.

25 Do members of the panel or the consultants have

1 any comments to make before we return to the general
2 discussion of damage propagation? They all look glassy-eyed
3 today. I think you did 'em in yesterday. They are not
4 feeling too frisky this morning, I can tell. The first
5 speaker is really lucky.
6 On my agenda I have Joe continuing.
7 MR. MUSCARA: Thank you and good morning.
8 I do not have too much to say this morning, but
9 we'll continue with the damage propagation with a
10 presentation from Dr. Shack on integrity of steam generator
11 tubes.
12 CHAIRMAN POWERS: You will have to tell us more
13 about his background and why he is qualified.
14 [Laughter.]
15 DR. KRESS: Is he qualified to speak to us?
16 MR. MUSCARA: If I were you, I wouldn't listen to
17 him.
18 CHAIRMAN POWERS: We don't in any case.
19 MR. MUSCARA: There is one comment I would like to
20 follow up from the last presentation yesterday.
21 I started yesterday talking about POD and the fact
22 that we need a robust POD test -- do not really come up to
23 100 percent, even for large flaws, and the reason I gave of
24 course was the human factor, but the human factor also
25 affects small flaws as well as large flaws. If the person

1 is blinking, whatever --

2 Another reason we don't always get 100 percent POD

3 for eddy current inspections of course is that the voltage

4 can be quite low. I am not sure how rare an event this is,

5 but you can get a flaw that is long and deep and provide you

6 a very small response.

7 In fact, I indicated yesterday the mockup contains

8 on the order of hundreds of tubes. Within these hundreds of

9 tubes we had about four flaws that were not detected by any

10 of the inspectors, the reason being they were small voltage

11 flaws, I believe below one volt.

12 In fact, these flaws are large. They are on the

13 order of up to two inches long, 80 percent deep or deeper,

14 so you can miss large flaws not only because of the human

15 factor but unfortunately they have low voltage response.

16 CHAIRMAN POWERS: On the first day of our

17 discussions of these phenomena we had something of an

18 explanation of why you would get that. I mean it was a

19 plausibility or intuitive description that they have lots of

20 these cross-ligaments in a tight flaw so they remain good

21 conductivity paths. Is that your understanding as well?

22 MR. MUSCARA: Precisely. This is my understanding

23 and speculation at this point.

24 However, whenever we have a test result like this

25 where it's been detected and we believe there are flaws

1 there and we have sized them with our own techniques we will
2 take the specimens out of the mockup and section them and
3 verify what the condition is and what might be causing the
4 low response, so our inspections indicated these are large
5 flaws.
6 I mean clearly we can see the length -- and by the
7 other methods we believe they are deep but we will section
8 some of those flaws to make sure that indeed they are deep
9 and whether there are a lot of ligaments with these.
10 MR. CATTON: How well does the search for flaws
11 perform when you look in the vicinity of the support plates,
12 or is this a part of this study?
13 MR. MUSCARA: In the mockups?
14 MR. CATTON: Yes.
15 MR. MUSCARA: Yes, the support plate is an area of
16 interest. There are flaws there and the techniques are
17 being used in the field for that kind of flaw being used in
18 the round-robin.
19 MR. CATTON: What is the POD?
20 MR. MUSCARA: Well, like I say, we are just in the
21 midst of pulling the data together and deciding what true
22 state for the generator is and conducting these evaluations.
23 At this point I really don't have the answer, but
24 we cannot have all this work, not all of it finished but
25 much of it finished so that we can have a topical report by

1 the end of this calendar year and at that point we may very
2 well have that information.
3 MR. CATTON: So it will be a part of what you do?
4 MR. MUSCARA: Oh, yes. In fact, we have included
5 with the support plate the complicating factors of the
6 crevices being blocked up but also denting, with assimilated
7 denting and superimposed flaws on the denting, so we made
8 the test reasonable enough that it represents the field
9 condition.
10 I think unless there are some other questions I
11 would like to have Dr. Shack come up and talk about the
12 integrity models.
13 DR. SHACK: Just for the record, I am Bill Shack
14 from Argonne National Laboratory and I qualified to speak on
15 this subject mostly because I have a bunch of competent
16 colleagues at Argonne who do the work.
17 Let me just hand out some toys. This is a steam
18 generator tube unflawed, pressurized to 2350 and taken to
19 840C, so this is what happens in the high dry sequence to
20 the unflawed tube if you get the temperature high enough.
21 It would be bigger except that we have a two inch
22 guard tube around this thing and so when it opens up and
23 smashes into the guard tube it kind of flattens out.
24 MR. CATTON: It becomes bubble gum.
25 DR. SHACK: I passed around a sample stress

1 corrosion crack yesterday that I thought everybody -- I
2 assume everybody found the 360 degree circumferential crack.
3 You might just want to compare what that looked
4 like in your memory with an EDM notch so you can see how
5 good a simulation an EDM notch is of a stress corrosion
6 crack.
7 Let me pass this one around after I do a little
8 bit of talking here.
9 I am just going to briefly review a lot of work
10 that was done by the NRC and industries during the '70s and
11 '80s to develop verified models for failures of flawed steam
12 generator tubes and I am going over that because some of the
13 work that we did at Argonne was to extend that work to the
14 short deep flaws. That was one sort of shortcoming in some
15 of the work that was done at PNL. They didn't have enough
16 short deep flaws, and so we wanted to go back and to extend
17 the model and do a little more testing just to see how we
18 were doing with the short deep flaws.
19 Then into this sort of traditional failure of
20 tubes under design basis conditions we have, as you have
21 heard, got into an extended sort of discussion of the
22 potential failure of steam generator tubes under severe
23 accident conditions, in particular under these high dry
24 scenarios where we have a depressurized secondary side and
25 then the core melting just drives the temperatures up to 700

1 or in fact if nothing else in the system fails to even
2 higher temperatures.
3 As I have noted, flawed tubes will fail at lower
4 temperatures but even unflawed tubes under the sort of 2350
5 pressure if you take them to 800 to 840C will fail rather
6 spectacularly.
7 Again as we get up to about 700C you can see the
8 flow strength of Alloy 600 is decreasing markedly and again
9 what we find of course is that in these tests, as you would
10 expect the failures at low strain rates are controlled by
11 creep and at high strain rates we expect them to be
12 controlled by flow stress.
13 We have typically found that we do better with
14 creep failure models, so we, whenever we can and we have
15 enough data, we try to work with the creep models.
16 For a part-through crack now let me say that
17 failure can mean two things. Failure can mean -- in a part
18 through crack means I have a crack that is, say,
19 three-quarters of an inch long but it is not all the way
20 through the wall. It's, say, 80 percent through wall.
21 Well, I can have the failure of the ligament when the crack
22 pops through the wall to create a leaking crack and that can
23 occur in two ways. That ligament can pop through but the
24 length of the crack doesn't change, so that is a stable
25 failure and what I end up with is a leak, and if I have a

1 three-quarter inch crack that pops through I have a leaking
2 three-quarter inch crack.
3 Unstable failure or burst means that the crack not
4 only pops through but will grow in length without any
5 substantial increase in pressure or burst, and what I have
6 here is a sample of a tube. It's sort of an interesting
7 one. It is a three-quarter inch long EDM notch, which is
8 sort of nice because you can make everything exactly
9 precise. It is 80 percent through-wall --
10 MR. CATTON: What kind of crack can you get with
11 the EDM?
12 DR. SHACK: It's about three to four mils.
13 MR. CATTON: And the walls are very smooth?
14 DR. SHACK: Yes. This is wide open. This is a
15 hole.
16 MR. CATTON: That's what I thought.
17 DR. SHACK: But from a structural point of view it
18 is a crack. That is, this is not a ceramic -- from Alloy
19 600 an EDM notch and a stress corrosion crack are the same
20 structurally. There's a difference certainly in leak rate
21 because the one is far tighter than the other, but as far as
22 the structural behavior goes, an EDM notch is a very good
23 simulation.
24 What you will see on this crack, you will see kind
25 of a bright, shiny line at the bottom. That is the

1 remaining 20 percent ligament, and if you look real
2 carefully you will see it slides off at a 45 degree angle.
3 It is a sheer lip failure -- that thing popped through.
4 Then you will see some tearing at the ends of the
5 crack, again on 45 degree lines as this thing is stablely
6 tearing. What happened is this one popped through at 2850
7 so we got the 20 percent ligament to fail at 2850 but it
8 wasn't an unstable failure. We had to go to 3000 psi before
9 we got the tearing at the ends of the crack and as it began
10 to extend in length.
11 Now again, what happens exactly when you start to
12 get the unstable tearing is kind of unclear because in all
13 laboratory systems we run out of pressure, and of course
14 when we run out of pressure the system stops growing. In a
15 real plant, yes, you'll run out of pressure but you will rip
16 a big hole and again after a hole gets so big it doesn't
17 make a whole lot of difference.
18 Once this crack is about an inch and a half long,
19 the crack opening is about as big as the diameter of the
20 tube and so the flow restriction is really the tube. It is
21 no longer the crack, so any crack lengths over an inch and a
22 half are almost kind of -- you know, not terribly exciting.
23 This is an interesting crack in the sense that it
24 would not have failed, even the ligament would not have
25 failed under a main steam line break, if you will allow me

1 just to use pressures for the moment.

2 MR. CATTON: The mild main steam line break.

3 DR. SHACK: The mild main steam line break, where

4 we just increase the pressure to 2500. Even the ligament

5 would not have failed but this is a tube that wouldn't pass

6 the 3 delta p criterion, so this is in that in-between

7 range, not good enough to pass 3 delta p, but it wouldn't

8 have even failed the ligament under the main steam generator

9 break, or shall we say the depressurized secondary loading.

10 MR. BALLINGER: What you are saying is this stuff

11 is pretty tough.

12 DR. SHACK: This stuff is pretty tough.

13 The bad news about Alloy 600 is it cracks. The

14 good news is it's tough as hell.

15 A variety of models have been used to describe the

16 failure, unstable failure of through-wall cracks and the

17 ligament failure. Most of them involve this kind of stress

18 multiplier factor. It is really a bulging factor and you

19 will notice that the axial tube here fails in a bulge way.

20 What I want to note is that this bulging factor

21 depends on the radius so curvature counts here and one of

22 the things that we will see, and we should keep in mind, is

23 that tubes are much weaker to axial cracks, because we have

24 this R-factor, and you can sort of see if I go to a flat

25 plate as R gets very large, this bulging factor goes down,

1 down, down and in fact I should have brought the flat plate
2 solution and one of the interesting things about a
3 cylindrical tube is that it has got a curvature in the hoop
4 direction and it is a flat plate essentially in the axial
5 direction, so that in fact axial cracks under the same
6 stress will open up a lot more than circumferential
7 stresses.
8 If I have, for example, a quarter-inch flaw in the
9 axial direction it will open about six times wider than the
10 same quarter inch flaw in the circumferential direction
11 because again under pressure loading I have a two-to-one
12 pressure ratio and I have a multiplier of about three
13 because of the curvature effect for the dimensions of this
14 tube, so again even if I had the same loading in the axial
15 direction that I had on the hoop direction the hoop crack
16 would open up about three times as much as the axial crack.
17 DR. KRESS: Bill, what is the V in that equation
18 or the Greek letter?
19 DR. SHACK: Here?
20 DR. KRESS: Yes.
21 DR. SHACK: Pousson's Ratio, .3.
22 DR. KRESS: Pousson's Ration, okay.
23 CHAIRMAN POWERS: Okay, keep going. What is C?
24 DR. SHACK: C is the half crack length. R is the
25 radius of the tube and T is the thickness of the tube.

1 CHAIRMAN POWERS: And the bulging factor is this
2 M --
3 DR. SHACK: M.
4 CHAIRMAN POWERS: -- which is not dimensionless?
5 DR. SHACK: Yes, it is dimensionless. That lambda
6 is a dimensionless quantity -- C over square root of RT.
7 DR. KRESS: Right.
8 CHAIRMAN POWERS: Okay.
9 DR. SHACK: In Christian units inches over square
10 root of inches squared.
11 For part through-cracks, we have a similar
12 formulation, but we have a different expression for the
13 bulging factor, and we won't worry too much about that.
14 There is a fairly extensive database that goes
15 through the burst pressure and the ligament failure
16 pressures to validate those correlations.
17 And, again, you'll notice, unlike the voltage
18 correlations, when you go to a more mechanistic correlation,
19 I can put 3/4, 7/8 and 11/16ths inch tubing all in the same
20 plot, if I non-dimensionalize with the square root of RT,
21 and I non-dimensionalize the burst pressure.
22 DR. CATTON: So what do you think is work with the
23 data that we looked at yesterday? It's just not presented
24 correctly?
25 DR. SHACK: With voltages, you can't

1 non-dimensionalize. There's nothing wrong with it; it's
2 just that you'll need separate correlations for 3/4-inch,
3 11/16ths, and 7/8ths-tubing.
4 DR. CATTON: I don't understand that.
5 DR. BALLINGER: If you knew the crack length
6 exactly --
7 DR. CATTON: So that's the problem; I don't know
8 the crack length.
9 DR. SHACK: The problem is that you don't know the
10 crack length.
11 DR. CATTON: Okay. I don't know what's causing
12 the particular voltage reading, okay.
13 DR. SHACK: The way I like to look at these things
14 is sort of a geometry failure map here, and I'm looking at
15 what happens to the whole range of flaw geometries that I
16 could have in terms of the length of the crack and the depth
17 of the crack.
18 And everything below this curve, all cracks here,
19 will have no failure at normal operating pressures, so I can
20 have three-inch crack, 85 percent through the wall, and
21 under normal operating pressures, that crack is going to sit
22 there with no problems.
23 If I have a crack that's one inch long, it will
24 pop through when it gets to be a little over 90 percent
25 deep, so it will pop through. But it will pop through

1 stably; it will pop through to give me a one-inch,
2 through-wall crack that will not grow in length, but will
3 sit there and will leak at some rate, and we'll talk about
4 leakage later.
5 However, if I had a three-inch crack that got to
6 about 87 percent deep, it would pop through and it would
7 start to run unstably until -- but again, three-inch crack,
8 once it popped through and opened up, I'm dead anyway.
9 DR. KRESS: Are those lines pretty thick?
10 DR. SHACK: No, those lines -- Yes, I should
11 mention that. The lines here, think of them as about an
12 eighth of an inch fuzzy line will cover the range of stress
13 of material properties that I have in the tubing.
14 So draw them with a magic marker kind of thing.
15 DR. BALLINGER: Does that include the vertical
16 line?
17 DR. SHACK: Yes, the vertical line will also
18 shift, depending on how things go.
19 Now, on some of the plots where it has mattered,
20 I've sort of shown the 95/95; on the plots where I haven't
21 shown it, just think of fuzzy lines.
22 Now, if I go to a main steam line break, the
23 geometry picture changes a little bit. Again, I need a
24 crack that's something over 70 percent through-wall of any
25 length to fail under the main steam line break conditions.

1 If I have shorter cracks, again, let's take a look
2 at the quarter-inch crack. That has to be about 95 percent
3 through-wall to fail, even under a main steam line break.
4 So, again, if we're talking about short cracks
5 popping through and leaking under these conditions, we're
6 talking about short, very deep cracks.
7 Again, anything below 85, you know, I need a
8 fairly substantial crack if it's not going to be at least 85
9 percent through-wall.
10 DR. CATTON: When you run these tests, everything
11 is nice and quiet, and the tube is sitting there.
12 DR. SHACK: We'll talk about that.
13 DR. CATTON: If you shake it just a little bit?
14 DR. SHACK: We'll talk about that.
15 DR. KRESS: That's saying under one inch never has
16 an unstable burst?
17 DR. SHACK: On a main steam line break, right.
18 DR. BALLINGER: How is the vertical line
19 determined? How is the dividing line determined?
20 DR. SHACK: Well, I have essentially a
21 through-wall crack margin and a pop-through margin. When
22 the pop-through pressure exceeds the unstable growth
23 pressure, that's when I get --
24 DR. BALLINGER: So it's experimentally determined?
25 DR. SHACK: No, no. It's analytically determined,

1 but it's also verified. Either the curve that you showed
2 there, showed the burst correlation versus the ligament
3 failure correlation, so this is one case when I know the
4 geometry, I can predict the stuff, you know, quite
5 accurately.
6 CHAIRMAN POWERS: Yesterday at some point in the
7 discussion we had a rule of thumb about crack depth being a
8 fifth of the length quoted to us for -- it was for
9 estimation purposes.
10 Is there some range of validity of those kinds of
11 rules of thumb?
12 DR. SHACK: I think that was trying to estimate
13 the shortest crack that would go through wall, and that
14 doesn't strike me as an unreasonable number. In a case like
15 this where there is no particular microstructure, to somehow
16 focus the crack growth and take it through, and that really
17 follows almost from fracture mechanics type arguments when
18 you look at the kind of growth that you could get in the
19 length.
20 Now, we can get longer cracks, you know. You can
21 obviously get cracks that are longer than five times the
22 depth, but I think that's a reasonable number for short
23 through-wall cracks.
24 But again, let's look at some of the consequences
25 of short through-wall cracks in a little bit, after I get a

1 little further along.

2 DR. KRESS: Look at these curves, Bill, where does

3 the 40-percent through-wall in the rule come from?

4 DR. SHACK: Okay, we're just about to get there.

5 DR. KRESS: Oh, I'm sorry.

6 DR. SHACK: Because, again, this is normal

7 operating pressure, main steam line break. But we're

8 looking for a three delta-P margin, and, you know, you're

9 always asking what is the margin?

10 Well --

11 DR. KRESS: Here, you really know what it is.

12 DR. SHACK: Yes. The NRC has determined that

13 three delta-P is it. You know, we go no lower. And the

14 answer, of course, is that an unflawed tube has a margin

15 that's probably nine times delta-P.

16 And you've allowed that to decay, but the margin

17 -- you know, you've said that it will go no lower than three

18 delta-P.

19 And you will notice that three delta-P, now, we

20 had sort of a 60 percent based on wastage, but again, you

21 get about the same number for a long crack. A short crack

22 can obviously tolerate a much deeper kind of thing, so,

23 again, short, deep flaws are not a problem.

24 DR. KRESS: But you go ahead and assume there's

25 long cracks?

1 DR. SHACK: Yes, but if you're going to assume
2 there's a long crack, then the 40-percent through, so, you
3 know, if you were -- if you were changing your 40 percent
4 rule, you might -- and if you thought you could predict the
5 crack depth, and you thought you could predict the crack
6 growth, then you might, in fact, do it based more on this
7 whole overall curve.
8 But, again, they've kind of argued that, you know,
9 you take a kind of an average, a worst-case kind of thing,
10 and you'll end up with the 40-percent through-wall.
11 DR. KRESS: But still this is 65 percent.
12 DR. SHACK: Yes.
13 DR. KRESS: It's not 40.
14 DR. SHACK: My guess is that they calculated the
15 60 percent based on a code minimum yield stress for Alloy
16 600.
17 DR. KRESS: I see.
18 DR. SHACK: I calculate -- Westinghouse did a very
19 nice job collecting yield and low stress data on all the
20 heats of Alloy 600 out there, and so I'm using sort of 95/95
21 and mean stress values on those kinds of yield stresses,
22 rather than code minimum, so, you know, a regulator may well
23 use a code minimum, but I'm a researcher, so I'm allowed to
24 be more realistic.
25 That's all very nice, but in many ways, we're

1 leak-rate-limited. You know, if you look at those curves,
2 you need big mother flaws to fail unstably, so in many ways,
3 it's leak rates that control these things.
4 And so what I've shown here is a crack opening
5 area versus crack length. And you can sort of see that
6 things start to get exciting here under normal operation
7 conditions when you get out to about an inch, and they get
8 very exciting when you get out to about an inch and a
9 quarter.
10 And, again, you begin to see a significant effect
11 of yield strength on the crack opening area that you get
12 from the longer cracks. And for reference here, I've sort
13 of shown the crack opening that corresponds to when you just
14 sliced the tube off and you've got the ID area in relation
15 to this crack.
16 And this curve is just this curve on a log scale
17 so you can really see what's happening down here in this
18 short crack range.
19 And, again, how do we calculate these? Well, we
20 calculate them from linear elastic fracture mechanics. We
21 use a particular model, due to Zahoor.
22 We've done essentially finite element analyses to
23 verify this model; we've done tests where we do essentially
24 room temperature leak tests so we can get a flow through a
25 crack and, you know, measure the area of the crack that way,

1 and then compare it with what we predict from the model.
2 We've take pictures of these cracks, scanned them,
3 digitized them, taken pictures of them.
4 And, of course, like all fracture mechanics
5 models, they're better, the smaller the deformation. You
6 know, these are all small deformation models, so that the
7 smaller the opening, the better.
8 But it is remarkable how well it does. We had one
9 of these little sort of freebie jobs we did for the Swiss.
10 They wanted some ruptured tubes. They were going to use
11 them for a test.
12 And, of course, being the Swiss, they didn't ask
13 for ruptured tubes; they wanted ruptured tubes with an
14 aspect ration of the crack opening to the crack length, and
15 they specified it.
16 So, you know, you're sitting here with a curve
17 that's about to go vertical, and you're trying to hit the --
18 DR. KRESS: You're trying to stop on that aspect.
19 DR. SHACK: You're trying to stop on the dime to
20 match the Swiss thing, and, of course, you know it -- but
21 the amazing thing is, that even for these rather large
22 openings, we were able to do a very good job at predicting
23 them from our model, and so we supplied designer ruptures to
24 the Swiss.
25 DR. KRESS: Now, when you do a finite element

1 around a crack like that, you have to get very small?
2 DR. SHACK: Yes, I can do the Zahoor analysis in
3 an Excel spreadsheet, you know, and the calculation takes
4 one blink of an eye.
5 DR. KRESS: But in your finite element, does the
6 crack end up at a short vortex?
7 DR. SHACK: No, it will round off.
8 DR. KRESS: It rounds off?
9 DR. SHACK: Yes, especially in these.
10 VOICE: [Off microphone.]
11 DR. SHACK: To look at the flow through these
12 cracks, there are a couple of things of interest, so
13 obviously the first thing if interest is the crack opening
14 area. That tells you how big the hole is.
15 But the other thing I want to know, is what's the
16 L over H? And, again, a lot of work was done on this for
17 stress corrosion cracks in piping, but stress corrosion
18 cracks in steam generator tubes are a little different,
19 because sometimes they look like holes, and sometimes they
20 look like long thin tubes.
21 So, if I've got a short crack, I've got an L over
22 H, depending on whether I'm in main steam line break of
23 something over a thousand, or, you know, 500, so I'm looking
24 down a very long narrow tube.
25 If I've got a crack that's more like half an inch

1 or three quarters of an inch, I've basically got a hole.
2 And so you get sort of different fluid mechanics models from
3 that.
4 The other thing that's interesting to look at --
5 and this is a plot that is not in your book, but it was
6 handed out as a separate viewgraph today -- and that's the L
7 over D for a leaking jet.
8 And, again, one of the things that's of interest
9 when you have a jet, of course, is the diameter of the jet
10 versus the distance it has to go before it impacts the
11 target.
12 And so we if we look at the L over D for a jet of
13 dimension .125 inches, since we had some concern about
14 cutting from steam jets of cracks of 1.25 inches or smaller,
15 we see for a 1.25 inch crack, the L over D is 2000.
16 DR. KRESS: What are you talking about here?
17 DR. SHACK: The .25 inches to the next tube
18 divided by the diameter of the exit jet.
19 DR. KRESS: Okay. That's just geometry.
20 DR. SHACK: Just geometry, just geometry, but it's
21 an important geometrical parameter to keep in mind.
22 DR. KRESS: Okay.
23 DR. SHACK: So for a .125 inch crack, it's 2000,
24 if I look that the L over D. Just as a point of reference,
25 the CFD calculations you were looking at yesterday were for

1 an L over D of eight.

2 DR. CATTON: Was it because they picked a really

3 big hole?

4 DR. SHACK: Yes. They're fluid mechanics guys,

5 and they don't know how big a crack opens up. They picked a

6 .5 millimeters that seemed like a good idea at the time.

7 Then they doubled it to 2.5.

8 DR. KRESS: These were rectangular holes. Is the

9 D there just the width of the --

10 DR. SHACK: We're talking slots here. Even a

11 quarter inch crack is an infinite slot when you look at the

12 crack opening here.

13 DR. KRESS: So when you say D, that's just the

14 width of?

15 DR. SHACK: The width of the opening, right.

16 Coming back to this crack opening area, let's just

17 talk a little bit about leak rates through these cracks.

18 We mentioned a model called Crack Flow that

19 Westinghouse uses. One of the simple-minded calculations is

20 just a simple pressure drop, you know, orifice model.

21 And the nice thing about that is, it gives you a

22 bounding leak rate. So if I take the full delta-P and I

23 divide it by rho, take the square root of two times that,

24 times .6, I get an orifice flow equation.

25 And if I apply that to .125-inch crack, I find I'm

1 leaking .03 gpm. So I'm not sending a whole lot of liquid
2 out of this crack, and, of course, it gets smaller at a
3 fairly rapid rate for cracks less than .125.
4 Now, in fact, of course, since my L over H ratio,
5 which I have shown here on this plot, even under a main
6 steam line break for this .125 inch crack, is about three or
7 four hundred. There is, in fact, a significant pressure
8 drop.
9 DR. CATTON: With pressure ratios like that,
10 shouldn't you use compressible flow equations?
11 DR. SHACK: Yes, but the non-compressible flow is
12 a conservative estimate, so my .03 gpm is a conservative
13 estimate. I'm just -- there is a variety of models. We
14 talked about Crack Flow, and, again, a lot of work has been
15 done on this in connection with stress corrosion cracking.
16 There's a model -- you know, Westinghouse has
17 Crack Flow, the NRC has Squirt. Professor Schrock has a
18 code called Source. EPRI has a code called PICEP, and
19 PICEP, Squirt, and Crack Flow use the -- again, you have to
20 do compressible flow models here.
21 And as Dr. Hopenfeld mentioned, there's a
22 non-equilibrium thing. There's a -- you start out as
23 liquid, and they flash to steam, but, in fact, you can get a
24 metastable state where the flashing doesn't occur when you
25 -- and it's not a thermodynamic equilibrium at all times.

1 And PICEP and Crack Flow use the Henry model for
2 discussing that transition from the non-equilibrium
3 situation to the equilibrium situation.
4 Professor Schrock has a different model that he
5 developed for the NRC. The code is called Source. There's
6 a NUREG on it.
7 He's done a fair amount of careful experimental
8 work, and I can leave it with the Committee, if they are
9 interested. But I think the important conclusion from
10 Schrock's experiments is that when you use the Henry model,
11 which is what Crack Flow uses, you're conservative.
12 And he says you can be conservative up to an order
13 of magnitude for the geometries that Schrock examined.
14 CHAIRMAN POWERS: Conservative with respect to?
15 DR. SHACK: Predicting mass flow through the
16 crack.
17 DR. KRESS: You predict more than you get?
18 DR. SHACK: You predict more than you would get.
19 So, you know, again, I haven't been through Crack
20 Flow to find out whether they do the sums correctly, but,
21 again, based on Schrock's evaluation of it, a model using
22 the Henry correlation for discussing the transition from
23 equilibrium or non-equilibrium transition, is going to give
24 you conservative results for the critical mass flow rate.
25 DR. CATTON: And Schrock is very careful.

1 DR. SHACK: Schrock is very careful.

2 DR. KRESS: When you say equilibrium, I'm not sure
3 I understand what you mean. I think you're talking about
4 metastable state, right.

5 DR. SHACK: It's not really equilibrium.

6 DR. CATTON: They talk about there's two; you can
7 talk about frozen flow, which means whatever the fluid is,
8 it stays at the inlet side conditions.

9 Or you talk about equilibrium flow. There it
10 thermodynamically adjusts at each stage along the flow path.
11 Or non-equilibrium flow where you can be -- the flow can go
12 further down the -- it goes down the hole and is not in
13 equilibrium with its pressure.

14 And that becomes a much more difficult kind of
15 calculation.

16 DR. SHACK: Yes, and Schrock does a true
17 metastable thing where's got basically a time constant.

18 DR. CATTON: What people should normally do is,
19 you do frozen flow, do equilibrium flow; and if they are not
20 too far apart, you quit.

21 DR. SHACK: Okay, one of my conclusions from this
22 is, because of the L over D ratio and the low mass flow
23 through the .125 inch crack and the very large L over D for
24 this thing, is that you're very unlikely to get steam jet
25 cutting from these short cracks.

1 The Argonne tests will be done for cracks that are
2 -- for geometries that are more characteristic of a .4 to .5
3 inch crack for which the L over D ratio is much smaller, and
4 you get much more mass flow through the crack.
5 DR. CATTON: How small? Is it still on the order
6 of 100?
7 DR. SHACK: What, L over D?
8 DR. CATTON: Yes.
9 DR. SHACK: Yes.
10 DR. CATTON: A hundred is still low.
11 DR. SHACK: We're going to run the tests.
12 DR. HOPENFELD: Will you give me one minute?
13 DR. SHACK: Sure.
14 DR. HOPENFELD: Because this is a very subtle
15 point, and I don't think I was really describing it at the
16 time because of the time that I had. I didn't get into the
17 detail, but this is an opportune time to express the point
18 exactly why is it important about whether it's one phase,
19 frozen flow, or whatever.
20 If you go back to your proprietary data, you see
21 that there was this extrapolation or equation, using the
22 equation of pressure and temperature, very simple square
23 root type equations.
24 I don't want to talk about it, but it's in your
25 data there. And there is a question, evidently, that people

1 who came up with those equations wanted to make sure that
2 they can justify that.
3 So, what they did, they went back to -- now I can
4 say what code it is. It's Crack Flow.
5 They went back there, and they used the voltage
6 data to come up with some kind of effective length, because
7 for the crack flow you need the length of the crack, right?
8 So they came up with some kind of a crack length as a
9 function of voltage, and then they plugged that thing back
10 and they got a line comparing that theoretical prediction of
11 crack with the database.
12 And they say, ah, well, that's fine; that looks
13 very good. Okay, and therefore we are confident in the
14 database that it has some theoretical justification.
15 And my point at the time was, wait a minute; you
16 can't say that, because you don't know whether you had a
17 two-phased flow in those tests or whether you had a
18 one-phased flow or what you had, because in that crack flow
19 you don't have the ten to the minus four metastability.
20 And there was the point, you know, is that
21 obviously can forget all the two-phase flow, and you would
22 be conservative, just the way you're doing it, and just
23 using an orifice equation.
24 And that probably is the way to do it, but my
25 point was that they are trying to justify that all that

1 database --

2 DR. SHACK: But my point is that because Crack
3 Flow uses the Henry Model, Schrock's results -- and, again,
4 I'll be glad to donate my coffee-stained copy of Amos and
5 Schrock to the panel, if they'd like to look at it -- it
6 says that those results will be conservative.

7 DR. HOPENFELD: I'm not questioning the
8 conservatism; I'm just trying to bring the point that the
9 line that the drew to compare with the database doesn't
10 really prove anything.

11 It doesn't get you a better feeling that they know
12 how to extrapolate from the laboratory test where the
13 pressure was not the same, to the steam line break; that's
14 my point. I'm not hundred percent right, that it's more
15 conservative.

16 DR. SHACK: No, the laboratory test was run. I am
17 almost positive that the laboratory test was run at the
18 right pressure. It might well have been run at a lower
19 temperature, because, again, it's a lot easier -- I can run
20 room temperature tests at 2500 psi without any difficulty.

21 Running tests at 2500 psi and 300 C is a more
22 expensive thing, so I suspect they were correcting for the
23 temperature.

24 DR. HOPENFELD: No. There was the delta-P wasn't
25 the same. The back pressure was not the same. I suggest

1 you go back there and take a look at it.

2 If it wasn't proprietary, I probably would have

3 picked up those points, but I suggest you go back there and

4 read all of that. There is a lot of material there.

5 And you'll find out now that that's why they have

6 all these corrections. And some of them came from foreign

7 data, and those were at room temperature, all very low

8 temperature.

9 So you've got to go back there and that was the

10 whole point. Besides those laboratory tests, those u-bands

11 or the samples that they had at MB-2, are the tube data that

12 was not run under typical conditions. Maybe some of them

13 were, but most were not.

14 DR. SHACK: I guess we could have a debate on just

15 how well you could make those corrections, but onward.

16 DR. CATTON: These things are scalable from one

17 pressure temperature to another.

18 DR. SHACK: I would argue that if you did it, you

19 know, what you do -- the thing that's undetermined in this

20 test is the crack area, the effective area. You can

21 determine that with one test under one set of conditions,

22 and then use the code to essentially extrapolate to other

23 conditions.

24 L over H is just -- you know, I have assumed the

25 simplest crack model. It's L in this case is a 50 mil wall,

1 and H is the crack opening. I should mention also if you
2 look at Amos and Schrock, his hydraulic diameter is 2H and
3 he can't divide L over 2H correctly, but we'll assume he
4 gets the thermal hydraulics right.
5 DR. KRESS: Would you repeat that?
6 [Laughter.]
7 DR. CATTON: I want that circled in the record.
8 DR. SHACK: Let's talk about circumferential
9 cracks. Again, the presence of a crack in a pressurized
10 tube produces bending, and the behavior can depend strongly
11 on whether this bending is constrained and on the fracture
12 toughness of the material.
13 And you end up with a fairly complicated looking
14 plot that looks something like this. And, again, if you
15 take a single crack or a tube with a single crack and you
16 pressurize it, what will happen is, it will bend.
17 And so the failure for that is this so-called
18 free-bending solution that you see right along here.
19 Now, the other thing we want to note is that for a
20 pressurized tube, if you're less than 100 degrees, you've
21 got a crack or not, this thing is going to fail in the axial
22 way, simply because of the 2:1 pressure ratio you have in
23 the tube.
24 So, you know, circumferential cracks don't even
25 start to enter the picture here until you've got 100

1 degrees, and then it matters whether you've got the
2 free-bending solution or what I have called the
3 fully-constrained solution that is when you constrain it
4 against bending.
5 You could do that with a teflon line or in a tube.
6 The easiest way to do it, experimentally, is to put two
7 symmetric cracks, one on each side of the tube, and then
8 you'll essentially have a fully-constrained solution and it
9 will look like this.
10 And so you'll be able, at any particular load --
11 or you can have a much bigger crack before you get failure
12 if you've got the symmetric loading, than you do if you have
13 the free-bending case.
14 Well, in the steam generator, we don't have free
15 bending, and we don't have fully constrained conditions.
16 We've got a tube support plate, you know, some couple of
17 feet above this thing, and we've got a tube, so this tube
18 has some flexibility.
19 And this is all covered in this Parameter C that
20 we have here. This is sort of a stiffness measure, and it
21 measures how much restraint you have, that that's a function
22 of the stiffness of the tube and the length that you have
23 between the supports.
24 In fact, the condition, if you assume it's simply
25 supported at both ends, or you assume it's constrained and

1 built in at both ends, if you look at steam generators, you
2 will find that this value of C is really somewhere between
3 .3 and .5. That would be a typical value.
4 And so that means that your curve sort of looks
5 like this.
6 DR. KRESS: What are you plotting?
7 DR. SHACK: I am plotting the pressure versus the
8 crack angle. And I want to know at what pressure will this
9 crack begin to extend unstably to grow? So it says under
10 normal operating conditions, I can have a crack that's 340
11 degrees through-wall, before it begins to extend.
12 DR. BALLINGER: We have an emaciated version of
13 that figure in the handout, at least mine is.
14 DR. SHACK: Oh, how interesting.
15 DR. KRESS: That's why I was asking you.
16 DR. SHACK: That's what happens when you send
17 McIntosh figures to people printing them from Word and a PC.
18 CHAIRMAN POWERS: I'm going to have to confess
19 that even in the fully-developed McIntosh version of it, I'm
20 a bit lost on this figure.
21 DR. SHACK: Okay.
22 CHAIRMAN POWERS: You're not plotting pressure
23 against something; you're plotting something normalized.
24 DR. SHACK: Right, the pressure over the burst
25 pressure of the unflawed tube. And so think of a curve that

comes from about here down to here, and then it goes to here.

That's the failure curve for a steam generator tube with a circumferential crack.

CHAIRMAN POWERS: Okay, now, on these squares and diamonds and circles, are those datapoints or simply indicators of some calculation?

DR. SHACK: No, that's -- I will get my staff to get out of the bad habit of putting symbols on curves that are purely calculations.

DR. CATTON: Those are purely calculations?

DR. SHACK: Those are purely calculations. So those are calculated curves for a range of stiffnesses. This would correspond to the distance of the tube support plate, to the -- from the tube sheet, and, again, as I say, for a real steam generator, the number is about .3 to .5.

DR. CATTON: For a given steam generator tube, you can calculate to C?

DR. SHACK: Yes. I didn't think you -- I can give you the formula for C, but this is a viewgraph.

DR. CATTON: I understand.

CHAIRMAN POWERS: What is the sigma, sub-Y over sigma-super-bar?

DR. SHACK: That's essentially the ratio of the yield stress to the flow stress in this material, and we've

1 got a power exponent, so it's a power law hardening material
2 with a power hardening exponent of .18. We're allowing
3 plasticity in this solution.
4 DR. BALLINGER: This flow stress is done by the
5 yield plus ultimate over two?
6 DR. SHACK: Over two, right. Again, I can give
7 you a detailed reference for the solution for the
8 circumferential support.
9 CHAIRMAN POWERS: Is ultimate over 2, so the ratio
10 of the yield to that obscure thing is a half, which means
11 ultimate and yield are the same?
12 DR. SHACK: No, no.
13 DR. KRESS: That is a material property is what
14 you are saying?
15 MR. BALLINGER: No, that is a rubric. Yield plus
16 ultimate over 2 happens to work.
17 DR. SHACK: I will take it back, I am not sure --
18 DR. KRESS: It is just the average.
19 DR. SHACK: This is something describing the power
20 law hardening curve that was used for these calculations.
21 This is -- we have done this three ways, with an elastic,
22 perfectly -- or an elastic, rigid plastic material, an
23 elastic tangent modulous material and a power law curve.
24 Exactly what this power law is, I will have to back and
25 check.

1 MR. BALLINGER: The yield plus ultimate over 2 is
2 used in general in all these calculations. It just happens
3 to work.
4 DR. KRESS: It just happens to work.
5 MR. BALLINGER: It just happens to work.
6 DR. SHACK: And Westinghouse and I, we will fight
7 over whether it is .5, .55 or .595.
8 DR. KRESS: But this is because you are failing in
9 flow plasticity.
10 DR. SHACK: Plasticity.
11 MR. BALLINGER: Plastic, it is a fully plastic
12 case and so yield plus ultimate over 2 is about an average
13 value for the flow stress.
14 DR. KRESS: About an average between, yeah.
15 MR. BALLINGER: And it works for strain hardening
16 materials.
17 DR. KRESS: Right.
18 DR. SHACK: Yeah. I will have to go back and
19 check this.
20 DR. KRESS: See, you have to explain these things
21 to us thermal-hydraulicists.
22 DR. SHACK: But the important thing is that you
23 can have extraordinarily large circumferential cracks in
24 this material.
25 Now, let's go back to the main steamline break and

1 some of the additional loads where, you know, I am only
2 calculating the pressure loads here. You know, these tubes
3 are thin wall tubes, so any axial force that I put on it
4 doesn't produce any hoop stress. If I have an axial crack,
5 without any change in hoop stress, I am not going to -- I
6 can change the axial stress, I am not going to do anything
7 to open that crack or to fail cracks in that direction. I
8 mean that is one of the fundamental assumptions of linear
9 elastic fraction mechanics is that I can have Mode 1, Mode 2
10 and Mode 3 cracking and they are independent.
11 DR. KRESS: So I don't have to worry about thermal
12 stresses then?
13 DR. SHACK: You do if you have thermal stresses
14 that will give you hoop stresses, but if you have thermal
15 stresses for axial cracks, if I have axial loads,
16 essentially, they have no effect on the axial crack. Now,
17 that is not quite true, there is kind of a second order
18 effect in this curvature thing, if you notice that bulge.
19 If I put an axial tensile load on here, I actually restrain
20 this tendency bulge by kind of a cable sense. And if I put
21 a compressive force on here, I would make it go a little bit
22 more. So there is a second order effect in a circular tube
23 under bulging because of that load, but that is a second
24 order effect, you know, it is pretty small.
25 DR. KRESS: That is when it already starts to go,

1 as opposed to whether it will go at all.

2 DR. SHACK: Right. Well, it could even have a

3 small effect on whether it starts to go, but I mean you

4 would really have to believe your calculations out to more

5 significant figures than I believe these models to worry

6 about that.

7 So I would argue that for the axial cracks, the

8 additional loads I might get under the main steamline break

9 will have very little effect on the crack opening or any

10 potential failure of those axial cracks.

11 MR. BALLINGER: The only complication might be in

12 the U-bend.

13 DR. SHACK: The U-bend. Well, again, we are

14 talking here 95-05 considerations, where we are in a

15 different beast.

16 DR. CATTON: The vibration caused by the event,

17 that is going to rattle them in every way.

18 DR. SHACK: But it is not going to put in this

19 kind of mode, the bulging mode for a circular tube. I am

20 going to have all sorts of bending modes, but all bending in

21 long, thin wall tubes produces axial stresses, you know, and

22 that is not true if I bend it enough to make it into a

23 U-bend, you know, if I turned it into a pretzel. But, you

24 know, these have been designed for these loads, I am not

25 going to get that kind of plastic deformation. You know, I

1 don't expect the steam generator to come apart and the thing
2 to bend over in a 90 degree bend. But, otherwise, I am not
3 -- I don't get coupling between the axial and the hoop
4 modes.
5 So the axial cracks, I don't really expect any
6 real major effect of the additional loads that I get from
7 the main steamline break.
8 Circumferential cracks, well, in the 95-05
9 context, --
10 DR. CATTON: When you make these arguments, what
11 kind of loading do you have in mind taking place inside the
12 generator? I can envision --
13 DR. SHACK: I am assuming it is not large enough
14 to fail the tube intention, yes. I mean if I had loads big
15 enough to fail the tube intention, I don't care whether I
16 have an axial crack or not. And, again, you know, the
17 blowdown loads here are not -- I don't exactly know what
18 they produce.
19 I know these things were designed for them, and I
20 know the way the code designs it, so I am assuming it was
21 designed to have perhaps a limited amount of plastic
22 deformation. You know, they would have somewhat relaxed
23 design criteria. You know, it wouldn't be pressure vessel
24 stresses, but it would be limited to some level.
25 Now, again, you can't make quite the same argument

1 on the circumferential stresses because I have axial
2 stresses now, and they act on circumferential cracks. But
3 in the 95-05 context, again, you have some circumferential
4 cracking in the tube support plate, but it is really
5 predominantly axial cracking if you look at all the
6 metalography. Much of the circumferential cracking is this
7 so-called cellular cracking, which is a kind of cousin to
8 IGA. Much of it probably is fairly shallow, is not
9 throughwall.
10 So, again, you have got -- and, as I mentioned, if
11 I had the same size axial crack throughwall, and the same
12 size circumferential crack throughwall, it would take three
13 times the stress on the axial, to open up the
14 circumferential crack as much as it would the axial crack of
15 the same length.
16 DR. KRESS: Why is it?
17 DR. SHACK: Because one is in a curvature and one
18 is in a flat plate.
19 DR. KRESS: Oh, I understand that part. But why
20 is it you get more axial cracks, a lot more axial cracks
21 that you do circumferential?
22 DR. SHACK: Oh, because I have got a 2 to 1
23 pressure ratio in the tube. You know, in the tube support
24 plate especially, the stresses, unless you have big dents,
25 which is a separate problem, is really the 2 to 1 pressure

1 stress that I have.

2 I get most of my circumferential cracking in these

3 things at places like the roll transition, where I put in

4 residual stresses which can be just as large in the one

5 direction as they are in the other, but overall, I mean that

6 is why can tolerate these mother cracks. You know, there is

7 nothing, this material is non-isotropic. It is not stronger

8 in the axial direction than it is in the hoop direction.

9 You get a head start because I am only putting half as much

10 load on it in the one direction as I am in the other.

11 Now, the other thing that does come in is the fact

12 is that in this direction it is a flat plate, and in this

13 direction --

14 DR. KRESS: It is a curve.

15 DR. SHACK: It is curved.

16 DR. KRESS: That is what I thought you were

17 explaining.

18 DR. SHACK: Yeah, and you get both of those

19 working together to make a difference.

20 CHAIRMAN POWERS: Bill, I must be particularly

21 dense today, or maybe typically dense, but you come to a

22 conclusion down here at the bottom of this that says that,

23 gee, even under MSLB conditions, throughwall cracks remain

24 stable until greater than 300 degrees extent. Is that just

25 an assertion, or am I to derive this out of this figure?

1 DR. SHACK: Main steamline break hits the
2 instability line at 312 degrees.
3 CHAIRMAN POWERS: Okay. Now, I didn't understand
4 that that was an instability line.
5 DR. SHACK: Yeah. The instability line, again,
6 comes down line so. So if I had very, very high, high axial
7 -- and that is the other thing now here, again, --
8 DR. KRESS: Below that, you get the crack may go
9 through.
10 DR. SHACK: I am assuming this crack is
11 throughwall already.
12 DR. KRESS: Already.
13 DR. SHACK: And all I want to know, if it is going
14 to get longer.
15 DR. KRESS: You are just trying to make it bigger.
16 DR. SHACK: I am just trying to make it grow.
17 DR. KRESS: Okay. So, below that, it is stable at
18 the size it is. And above that, it is going to run.
19 DR. SHACK: Right. So, again, if I had a 200
20 degree crack, I can put an awful lot of extra load on this
21 thing. Again, I don't know how much I get in these things,
22 but I can put an awful lot of extra load. And I really
23 don't think that Gary and Jack are going to allow people to
24 operate with 200 degree cracks circumferentially.
25 CHAIRMAN POWERS: The problem is that their

1 detection ability of sort of circumferential cracks is much
2 lower.
3 DR. SHACK: But, again, in the 95-05 context, big
4 circumferential cracks are very, very unlikely and have
5 never been seen. You know, big circumferential cracks occur
6 at the tube support plate, I mean the tube sheet, the roll
7 transition.
8 DR. KRESS: Now, this whole discussion has to do
9 only with circumferential cracks, right?
10 DR. SHACK: Yeah, I did failure for the other
11 cracks back in this diagram.
12 DR. KRESS: That was the unstable.
13 DR. CATTON: We also had to put an adjunctive in
14 front of MSLB, "mild."
15 DR. KRESS: But on the other diagram, the previous
16 one, Bill, go back to the previous curve. I am doing it,
17 Dana.
18 CHAIRMAN POWERS: Well, that is good because I am
19 totally perplexed on these figures.
20 DR. KRESS: Where is your P for main steamline
21 break? Oh, you have got main steamline break calculated
22 separately, okay.
23 DR. SHACK: Right. Then I show the three curves
24 together here to show you the sort of different ranges of
25 crack geometries that are of interest if you are in the

1 operating range, in the main steamline break range, or the 3
2 delta P. So the 3 delta P requirement essentially removes
3 this range of cracks.
4 DR. KRESS: So the conclusion we draw from this
5 main steamline break figure is that you have to have pretty
6 deep cracks, like 75 percent throughwall, before a main
7 steamline break increases its flow area.
8 DR. SHACK: Right. Well, you have to have more
9 than -- you have to have 75 percent throughwall before the
10 crack will even pop throughwall.
11 DR. KRESS: Oh, yeah, that is right.
12 DR. SHACK: And, again, so if I had a long enough
13 crack at 75 percent, I would go through the wall, and I
14 would go -- but it so long, I don't care whether it is
15 unstable or not. You know, a leak that big is -- I am
16 already dead.
17 DR. KRESS: You are already dead.
18 DR. SHACK: Here, to get a leak from smaller
19 cracks of interest, I have to be .8 to .995 throughwall.
20 DR. KRESS: Which kind of tells you you don't need
21 to worry about main steamline break imposed loads for either
22 axial or circumferential.
23 DR. SHACK: No, no, that is not the message. The
24 message is that only certain cracks fail.
25 DR. KRESS: Oh, I see.

1 MR. BALLINGER: The fact is that you can miss a
2 long, 2-1/2 inch crack --
3 DR. KRESS: You can miss it, it might be there.
4 MR. BALLINGER: that is 70 percent throughwall.
5 DR. KRESS: And it is going to go through and
6 leak.
7 MR. BALLINGER: And then it will rupture.
8 DR. SHACK: Again, here is my implications from
9 all this again. I have left everybody confused, but here is
10 what I draw from this anyway. I am going to argue that,
11 again, talking more generally now, not in the 95-05 context,
12 that the primary mode of interest is this stress corrosion
13 crack. It is going to be associated with regions of high
14 residual stresses or aggressive chemistries.
15 The places that I am going to find that are the
16 tube support plate where I have crevice conditions that
17 promote aggressive chemistry. The roll transitions, again,
18 I have got high residual stresses there, I can get cracks on
19 the ID, I can get cracks on the OD, I can get axial and
20 circumferential cracks. Roll transition is a bad place.
21 Small radius U-bends, I get residual stresses
22 introduced during the fabrication process simply in bending
23 this thing around to make a U-bend, and as that radius gets
24 tighter, the stresses associated with that operation get
25 higher.

1 DR. KRESS: Are these steam generators small
2 radium U-bends?
3 DR. SHACK: Yeah, this is -- think Row 1, Row 2.
4 DR. KRESS: Row 1, all the ones right in.
5 DR. SHACK: Yeah, right. You know, are the tight
6 ones, I could have said it that way. You get additional
7 stresses if you have got hour-glassing of the flow slots by
8 denting and you move the legs of those things together.
9 And, again, I would argue that the cracks in the
10 small radius U-bends have the greatest potential for gross
11 failure. In the tube support plate, your cracks are limited
12 by the thickness of the tube support plate and opening and
13 leakage is constrained by the tube support plate, except
14 perhaps in main steamline breaks.
15 The high stress transition at the roll transition
16 is limited in extent, it is typically less than 10
17 millimeters. So I am going to get axial cracks that are
18 fairly limited in length, although I can get big
19 circumferential cracks, but I have argued that I can
20 tolerate pretty big circumferential cracks.
21 So, of the three main regions here, the small
22 radius U-bend, as Ron said, I can have a four to five inch
23 long crack, I have got a high stress region that is long in
24 the small radius U-bend, so I can get a big crack.
25 Now thoroughly confusing everybody, let's move on

1 to high temperatures, where I can really do it.

2 MR. STROSNIDER: Bill -- this is Jack Strosnider.

3 I was wondering if I could just interject a though before

4 you do move on to that.

5 I mentioned yesterday when we talked about the

6 steam line break issue that I didn't see this necessarily as

7 a Generic Letter 9505 issue. I thank Bill. I think he has

8 provided some quantitative arguments in that regard.

9 When I first looked at this issue, the thing that

10 comes to mind is exactly what Bill said. My concern would

11 be stress corrosion cracking at the top of the tube sheet in

12 the roll transition where we have had some significant

13 circumferential cracking.

14 The one thing I wanted to make you aware of is --

15 or a couple of things -- is inspections that licensees are

16 doing they are using rotating pancake coil probes at the top

17 of the tube sheet. If they know they have got that cracking

18 going on, they basically do 100 percent. In their initial

19 inspections by EPRI guidelines they would be doing 20

20 percent and if they find something they expand it to 100

21 percent.

22 The other thing I would mention with regard to the

23 fracture analysis here is Bill -- the analysis that is

24 presented here is dealing with planar cracks. Actually when

25 you look at these cracks that are occurring in the roll

1 transition they are not really planar. They tend in that
2 residual stress field of about a quarter to three-eighths of
3 an inch to be offset as you go around the tube and actually
4 some of the testing of those tubes in situ and where they
5 have been removed show that they have very, very high
6 failure strengths because of the ligaments that are there,
7 that they will leak, all right, and quantifying that leakage
8 is another question, but in terms of actually failing it
9 they do --
10 DR. SHACK: Just to expand that little bit, Joe
11 showed you a figure yesterday, it's in his presentation, of
12 a probably more realistic depiction of circumferential
13 cracking at a roll transition where he had four parallel
14 rows of cracks sort of spread out across the roll transition
15 and they went 360 degrees but they were segments, so -- and
16 as Jack said, when the guy does the normal kind of
17 inspection he is going to see that as a 360 degree crack.
18 It is going to look horrendous to him but when you see the
19 detailed resolution of that thing, it is really a whole
20 bunch of short little cracks and I suspect if we blew that
21 tube up we would find it probably had a pressure stress of
22 6,000 to 7,000 psi.
23 The other thing that we have seen --
24 CHAIRMAN POWERS: Well, let me interject here.
25 If you expect us to take this into account we're

1 going to have to see the data and if you are arguing for
2 taking a stand on high pressure we are going to have to see
3 that.
4 MR. BALLINGER: The actual field experience has
5 been that apart from fatigue failures there has not been a
6 tube rupture, correct me if I am wrong, due to a
7 circumferential crack other than fatigue.
8 CHAIRMAN POWERS: We have got 11 incidences of a
9 tube rupture. That does not constitute a database that
10 seems to preclude this.
11 MR. BALLINGER: I said field experience, not
12 database.
13 MR. STROSNIDER: I think we can provide some data
14 from the Maine Yankee experience I think where they did
15 some, my recollection is some in situ and maybe some pulled
16 tube tests and they did some metallography on this. We will
17 have to pull that out for you.
18 The final comment just for you to be aware of is
19 that with regard to circumferential cracks at the top of the
20 tube sheet and for cracking in the U-bend and some of these
21 areas we are talking about the plugging criteria is plug on
22 detection and anything that is detected is removed from
23 service.
24 Then you get back to what is the threshold of
25 detection and we had some discussions on that yesterday, all

1 right, and so anyway I just wanted to interject those
2 thoughts and we can provide some information on the cracking
3 at the top of the tube sheet.
4 CHAIRMAN POWERS: It seems to me that in our
5 discussion the probability of detection would -- I came away
6 with the impression that you difficulties in detection are
7 precisely in the areas that this slide says are our greatest
8 concern, the U-bend and the top of the tube sheets.
9 DR. SHACK: We have got the tube support plate
10 9505.
11 MR. STROSNIDER: And I would also point out that
12 with rotating pancake coil inspections at the top of the
13 tube sheet and the inspections that people are doing there,
14 and again recognizing the forgiving nature of those
15 particular defects I think we are in pretty good shape
16 there.
17 Clearly there are some issues in the U-bend. We
18 got Indian Point 2 in February where there was clearly a
19 threshold of detection problem. The crack that failed was
20 there in the last inspection but the quality of the data was
21 so noisy that they didn't pick it up, and that is something
22 we are dealing with.
23 The industry is currently working to incorporate
24 some noise criteria if you will into the EPRI guidelines and
25 we are working on a generic communication on that same

1 subject.

2 CHAIRMAN POWERS: And one can't help but wonder

3 how many more of these discoveries we have to make before we

4 come away with the enthusiasm that we should on this

5 detectability issue.

6 MR. STROSNIDER: Well, the only point I would

7 make, and I think Ken Karwoski -- you can paint a very dark

8 picture if you want, but I would also go back and look at

9 the actual data on the decrease in the number of leaking

10 tubes, the decrease in the number of tube failures.

11 If you look at those failures that we are talking

12 about, it is a large number up through 1993 and one since

13 then. It may not be statistically significant but I would

14 suggest that the advances that we have been talking about in

15 the inspection methods and the programs that are being

16 implemented are having an effect, so I wouldn't paint too

17 dark a picture.

18 CHAIRMAN POWERS: I would be interested in looking

19 at the number of tube rupture accidents that we have had on

20 a per year basis and see if that has come down equivalently.

21 MR. STROSNIDER: Say that again?

22 CHAIRMAN POWERS: The number of tube rupture

23 accidents that we have had --

24 MR. STROSNIDER: One for five years --

25 CHAIRMAN POWERS: Which is about the same rate

1 they have been going on before, so I mean nothing has
2 changed on that.
3 MR. STROSNIDER: It doesn't matter whether it is a
4 40 percent through-wall criteria or --
5 DR. SHACK: Well, as Jack pointed out, the
6 criterion here is not 40 percent through-wall. It is plug
7 on detection.
8 MR. STROSNIDER: Right, but the point I made is
9 that the data, I agree, may not be statistically significant
10 in terms of the change of the rate of tube ruptures but I
11 would suggest t hat if you look at the frequency of
12 ruptures, if you look at what happened in the '70s and '80s
13 and you look at what happened in the '90s and you add a
14 little bit of knowledge about the new inspection methods,
15 the use of the plus-point probe, the 100 percent
16 examinations, the scope of what is being done, all right, I
17 can't show it as statistically significant but I would not
18 want to discount it.
19 MR. CATTON: I think before you completely close
20 it out, we have got to find out what happens with GSI 188.
21 That is really where it's at.
22 For mild MSLBs you give a very convincing
23 presentation.
24 MR. MUSCARA: I want to go back to this issue on
25 the detection of circumferential cracks.

1 You mentioned previously now that we know that we
2 expect cracks at the top of the tube sheet we can at least
3 do inspections in those areas, not with bobbin coils but
4 with pancake coils.
5 As I mentioned yesterday we are doing quite a bit
6 of work to quantify inspections in that area also and what
7 we find is, yes, there's difficulty detecting small
8 circumferential cracks but the largest circumferential
9 cracks PODs do not do that -- it's fairly high -- and so if
10 we are talking about a 340 DB crack that you need to open
11 up, those are not missed. The smaller ones, yes.
12 DR. SHACK: I didn't mention it and I can't find
13 the transparency at the moment -- oh, here it is -- the
14 other thing you want to note is that the leak rates --
15 again, this notion that these big cracks -- these leak rates
16 are still fairly small through these cracks again out to
17 100, 150 degrees.
18 You are not getting a lot of leakage out of the
19 circumferential cracks.
20 CHAIRMAN POWERS: Bill, I guess I really am dumb
21 today. You've got a plot of a quantity that on the
22 appearance of it is nondimensional.
23 DR. SHACK: Yes.
24 CHAIRMAN POWERS: Okay.
25 DR. SHACK: It is the area over the flow area of

1 the tube.

2 DR. KRESS: There's sort of a leak rate.

3 DR. SHACK: Sort of a leak rate. Multiply by 600

4 gpm.

5 MR. BALLINGER: Is that where it is normalized to?

6 DR. SHACK: That is the one number that everybody

7 seems to be able to agree on is that if you have the tube

8 cut you will get 600 gpm.

9 We'll figure over CRACKFLOW and Henry versus time

10 relaxation but 600 gpm out of the end of the tube seems to

11 be a number we can all agree on.

12 CHAIRMAN POWERS: But if I do that, then I get

13 some reasonable numbers, don't I?

14 DR. SHACK: Yes. Those are big cracks though.

15 CHAIRMAN POWERS: I guess I don't understand why

16 it is small. I mean when I do the multiplication I don't

17 come up with a small number.

18 DR. SHACK: It is a small number --

19 CHAIRMAN POWERS: The flow relative to 600 I'll

20 agree but --

21 DR. SHACK: It is also small for a 150 degree

22 crack. That is a big crack.

23 Let's go on to high temperatures.

24 We are looking at the failure steam generator

25 tubes during a severe accident. We have got -- we have done

1 these tests. Essentially we wanted to bound the kind of
2 things that we're predicting -- I will learn to spell this
3 thermal hydraulic one of these days --
4 [Laughter.]
5 DR. SHACK: -- which sort of predict that we have
6 a range of something like 3 to 13 C per minute, kind of a
7 heatup rate. If these ramps are sufficiently rapid we could
8 depend only on the burst properties and they'll be history
9 dependent. We could use a flow stress model.
10 If they are sufficiently slow we have to take into
11 account the pressure and temperature history. We use a
12 creep rupture model.
13 The thing that we have noted, at normal operating
14 pressure we account for crack geometry through a stress
15 magnification factor, MP. We have an extensive database to
16 validate that at those temperatures, but we find from
17 analyses that if we take the kind of stress-strain curve
18 that we expect to get at 300 C and the kind of stress-strain
19 curve we expect to get at a much higher temperature, much
20 less strain hardening, we find that it doesn't make a whole
21 lot of difference in the MP that we calculate, so that MP is
22 really a measure more of geometry than material properties,
23 and we can use it in high temperature and at low
24 temperature, so that is an assertion.
25 We have to sort of demonstrate then that it works.

1 We are going to assume that the MP factors we
2 derive from low temperature tests are applicable and we are
3 going to determine failure by a creep time fraction model.
4 This is a sort of linear damage rule where we kind of scale
5 the rupture time according to the stress and temperature and
6 so if we run tests at one temperature and one stress and
7 then we are doing a variable stress history we can
8 essentially integrate that fraction of the damage that
9 occurs at that particular stress and temperature and just
10 sum it up until we to get to one for failure.
11 The stress that is active here is the actual
12 stress time, this multiplier MP that we have determined
13 comes from the flaw geometry.
14 What do we do for the validation tests? We did
15 isothermal constant pressure tests. We did some tests with
16 deep cracks to test how well the MP model was doing. We did
17 constant ramp rate tests where we just ramped up the
18 temperature with either a constant pressure temperature ramp
19 or an isothermal pressure ramp, so we did the ramp tests.
20 Then we did prototypical tests under varying --
21 some of them were more prototypical than others but they all
22 varied.
23 Here are some results comparing the results we get
24 from essentially the Creep Model and the Flow Stress Model.
25 We're looking at two different ramps here that

1 we've called the EPRI ram and the INEL ramp, and you may
2 remember those from the good old days, and Steve may bring
3 them up again, or he'd probably rather forget them all.
4 But they were --
5 DR. CATTON: This was an increase in temperature?
6 DR. SHACK: Yes, this is -- you know, was
7 essentially a projection of the temperature during the
8 station blackout accident.
9 And --
10 DR. CATTON: By EPRI and INEL?
11 DR. SHACK: By INEL.
12 DR. CATTON: They're probably both too low.
13 DR. SHACK: Well, the answer is, they are
14 different, but we managed to predict both ramps. We do the
15 constant pressure ramp, so you give us the ramp and we'll
16 predict the failure. That's the message.
17 Circumferential cracks, we don't quite as well,
18 but we do it enough.
19 CHAIRMAN POWERS: Let me see if I understand. The
20 symbols here are the datapoints and the line is the
21 prediction model?
22 DR. SHACK: No, the line is -- below the line,
23 you're --
24 CHAIRMAN POWERS: Okay, that's 100 percent
25 correlation?

1 DR. SHACK: That's the 100-percent correlation
2 line.
3 Okay, one of the other quantities of interest here
4 is the crack opening area at high temperatures, because
5 we're worried about leakage at high temperatures.
6 So we've calculated crack opening area under 300 C
7 conditions. There were a couple of questions that came up
8 here.
9 Is there any creep crack growth that occurs before
10 this crack goes unstable? That is, if we've got a crack
11 that's existing and we're now heating up the tube, can the
12 creep crack growth just make the crack get longer, so if we
13 start with a quarter inch crack at 300 C, by the time we get
14 to 700 C, will it be longer than a quarter inch or will it
15 just open up.
16 And, again, we're petty sure the crack opening
17 area is going to vary with time, and we want to be able to
18 predict that.
19 The analytical predictions are based on a an
20 analogy between a power law plasticity model and creep
21 behavior. What we do is, we take essentially the power law
22 plasticity model and we replace the strain by the strain
23 rate in the creep solution.
24 And we've got power law plasticity models for
25 center crack plates. The difference between the axial crack

1 and the circumferential crack is the fact that you get this
2 additional stress on the axial crack because of the bulging
3 factor.
4 So what we've -- we can't do tests on an axial
5 crack at high temperature without an infinite amount of
6 money. But we can pull on a tube pretty easily at high
7 temperature.
8 So what we've done is pulled on the tube at high
9 temperature, but we've said that the stress we should use is
10 M times the hoop stress.
11 So we've essentially done the axial loading with a
12 much higher stress to account for the fact that we haven't
13 got the curvature, so we've replaced the curvature with
14 essentially a higher stress to get an equivalent model.
15 DR. BALLINGER: Can I ask what COD is?
16 DR. SHACK: Crack opening displacement.
17 DR. CATTON: I should have known that one.
18 DR. SHACK: Okay, well, this sort of just says we
19 can't do these tests on the through-wall axial crack tubes,
20 and it's under internal pressure and it would take an
21 infinite gas supply system.
22 We thought about doing it on cracked plates, but
23 then we decided that the easiest thing to do was to take our
24 tubes and just put some symmetrical notches on both sides.
25 As I mentioned, that puts them -- it's like a flat

1 plate, but it just happens to be a repeating flat plate with
2 a period of pie-D.
3 So, there is it. You've got symmetric cracks.
4 And that's basically equivalent to this flat plate solution
5 with two cracks.
6 And we're good, we can do flat plate solutions,
7 and we like those.
8 Then we did a couple of different kinds of tests.
9 We did these isothermal validation tests, where we just
10 heated the temperature up to near 700-C.
11 We put a load on it, and we predicted how the
12 crack would open as a function of time.
13 And so again we've got a constant load, we've got
14 a constant temperature, and the crack is just opening up as
15 time goes on. And so you can sort of see how it's going up,
16 and we've got the observations versus the predicted.
17 And we've done this at two different load levels.
18 CHAIRMAN POWERS: For higher loads, you started
19 with deviation? Is there any significance to that? I mean,
20 if I went to 3,000 pounds, would I see a much bigger
21 deviation?
22 DR. SHACK: I don't know. We would have to run
23 the test.
24 CHAIRMAN POWERS: You don't have an explanation?
25 DR. SHACK: I don't have a good explanation for it

1 now. Those we did with two 45-degree notches. We wanted to
2 go back and do some more sort of notches that we thought
3 would be more protatypical, which is a .25 inch kind of
4 thing, the kind of small notch that Steve worries about
5 opening up and losing flow out of in the high temperatures.
6 And, again, this is another one of these
7 isothermal validation tests, and, again, the way we do these
8 essentially, it's sitting in the furnace. We open the
9 furnace up, we peek in with the telescope, make the
10 measurements, close the furnace back up. We're doing the
11 cheap.
12 CHAIRMAN POWERS: The High Temperature Committee
13 developed better ways to do that, by the way?
14 DR. SHACK: You know, on our budgets --
15 DR. CATTON: Sometimes that's where the best work
16 is done.
17 DR. SHACK: Now, we wanted to do a non-isothermal
18 validation test, and in this case, we used the temperature
19 ram simulating six RU. This is probably the temperature
20 ramp that Steve will show you today. This is the one they
21 believe is the -- Joe will show you.
22 Now, of course, when we're doing the isothermal or
23 the transient, we can't open the furnace up. So here we
24 only get one datapoint.
25 You know, you hit it, baby, or you miss it, so

1 here's the temperature, here's the predicted notch
2 displacement as a function of temperature, but the only
3 point we can validate is the one right there at the end.
4 And, again, we were doing pretty well on the --
5 DR. BALLINGER: You're going to get -- an LA-600
6 is going to be well behaved in that respect, because you've
7 got that cliff at about 650 C where the yield strength drops
8 off like a stone.
9 So you're into the creep regime and it works.
10 DR. SHACK: Well, the other nice thing about this
11 that we're always surprised about is, in the creep regime, a
12 lot of this heat-to-heat variation goes away.
13 You know, that all arises from the differences in
14 the working that you've done, and you heat that up, and that
15 all goes away and we're sort of left with the basic,
16 fundamental crystal structure of Alloy 600, and so you get
17 much less material-to-material variation in the creep
18 regime.
19 If we just look at these things, they open up into
20 rectangles. You know, there's no creep crack growth here.
21 They don't get any longer, the suckers just move apart, and
22 they turn into rectangles.
23 So they started out as narrow slots and they
24 opened up as wide slots.
25 DR. BALLINGER: It's tough stuff.

1 DR. SHACK: Tough stuff.

2 Now, this crack opening area begins to, again,
3 increase rapidly. If you look at this crack opening area,
4 it sort of goes along, along, and as Ron mentioned, you
5 know, you kind of fall off this cliff around 650, and the
6 action starts to take place, so that basically there's not a
7 whole lot of increase in the crack opening area till you get
8 out to about 650, and then it starts to take off.

9 And so what we've done here is looked at --
10 suppose we had a final temperature of 700 C before something
11 else failed or if we had a final temperature of 750 C, you
12 can predict the crack opening areas, at the crack length at
13 those two temperatures.

14 You can also predict the leak rate through those
15 crack opening sizes, again, as a function of crack size at
16 the two temperatures.

17 CHAIRMAN POWERS: It's easy to compare these
18 because these are in kilograms per second, as opposed to
19 gallons per minute, right?

20 DR. SHACK: Well, I had them as gallons per minute
21 when I started out, but they told me that when we deal with
22 gases, we do it in kilograms per second.

23 Well, that was all I wanted to say -- well, let me
24 just -- we've got a couple of extra ones.

25 Life gets harder when you get to the real world,

1 of course, because when somebody hands me a real crack, it
2 never looks like a rectangle, unfortunately, and so you have
3 to make some sort of judgement as to how you're going to
4 model this crack in terms of an equivalent rectangle.
5 And there is a discussion of how to do this, and
6 there are some various procedures that we're trying, that
7 people use, and we've --
8 Without going through them, we're trying to
9 validate those kinds of procedures by looking at, again,
10 controlled shapes. It's easy to triangles and trapezoids,
11 and you kind of compare what you get in burst pressure from
12 the triangular and trapezoidal notches with essentially the
13 equivalent area kind of models that we're working through.
14 Again, that's more of a detail, I think, than we
15 need to get into here, but it is a question that has to be
16 addressed. And that's where we're going.
17 Any questions?
18 [No response.]
19 CHAIRMAN POWERS: Any other questions for Dr.
20 Shack? Anyone that thoroughly understands everything that
21 he's told us?
22 Okay, that's good. Thank you, Bill.
23 Are we -- did we exhaust the subject of crack
24 unplugging yesterday?
25 MR. STROSNIDER: I don't think we have anything

1 else to present in that area.

2 CHAIRMAN POWERS: Okay. It's just listed on my

3 agenda here, and I know we talked about it a lot.

4 One of the issues --

5 DR. SHACK: My L over H curve is sort of a crack

6 unplugging model. It's easy to unplug cracks of L over Hs

7 and too big. The bigger it gets, the harder I would suspect

8 it would be to unplug the crack.

9 CHAIRMAN POWERS: I don't pretend to understand

10 that.

11 One of the issues that falls under the general

12 nature of crack unplugging is probably also material coming

13 out of the crevice regions.

14 Do you have anything that you'd like to talk about

15 on that aspect of crack unplugging? That was an area that

16 we didn't explore yesterday.

17 MR. STROSNIDER: Are you talking about loss of

18 material between the tubes, the plate and the tubes?

19 CHAIRMAN POWERS: Right.

20 MR. STROSNIDER: Okay, I don't know if there is

21 anything for me to talk about.

22 MR. KARKUOSKI: Just in that area, the only thing

23 I would add is that when we do these leak tests, these leak

24 tests are performed as if that degradation is in the free

25 span so if there's any material that stays around the tube,

1 it would only serve to restrict the leakage. The
2 correlations are all based on free span tests.
3 CHAIRMAN POWERS: Okay. That's actually very
4 useful.
5 Okay, if that exhausts that discussion, then I
6 think we can afford to take a break till quarter after the
7 hour.
8 [Recess.]
9 CHAIRMAN POWERS: Let's go back into session.
10 We are now going to discuss the accident framework
11 for a lot of these technical issues that we have been
12 covering. We have made a distinction, appropriately I
13 think, between design basis accidents and severe accidents,
14 but to my mind some of these things cloud the definitions of
15 the distinctions that one likes to draw between design basis
16 accidents and severe accidents.
17 In particular, the essence of my challenges here,
18 it seems to me is in the design basis analysis one analyzes
19 a main steam line break and one analyzes steam generator
20 tube rupture accidents, and one is supposed to have a plant
21 that accommodates both of these.
22 Now one has a situation where a main steam line
23 break involves a steam generator tube rupture, which up till
24 now has never been done as a design basis accident, and so
25 design-basedness becomes a little more complicated.

1 One of the areas that it becomes very complicated
2 in thinking about actually comes back to the iodine spiking
3 issue, that in the past we have said okay, let's calculate a
4 spiking value looking at what the steady state coolant
5 concentration is according to the tech specs.
6 Now you have plants operating much lower than the
7 tech spec limits though they may have not changed their tech
8 spec limits. Even if they did change them, they are still
9 operating a couple more at the risk magnitude below.
10 Now if one hypothesizes that the spiking factor
11 that one has is inversely correlated with that coolant
12 concentration, it seems that if one follows the prescription
13 of design basedness, that's fine, but I still use the tech
14 spec limits following that, but that is a lower spiking
15 factor than one would have if one used the operational ones,
16 so things get very confused between realistic and design
17 basis.
18 Anybody that can help me understand these a little
19 better I would appreciate it. That is your cue, Gary.
20 MR. HOLAHAN: This is Gary Holahan. In fact, the
21 Staff will make a presentation on both design basis and
22 severe accident issues. Steve Long is going to start off in
23 fact trying to define what we mean by design basis
24 accidents.
25 I would say something a little different from the

1 way you introduced it, Dr. Powers, and that is I think that
2 we are still preserving the concept of design basis, meaning
3 looking at spontaneous tube ruptures and looking at steam
4 line breaks, not steam line breaks with tube ruptures, but
5 we are looking at steam line breaks with increased leakages
6 that may be associated or expected to occur given the main
7 steam line break.
8 We also have severe accident analysis which looks
9 at main steam line breaks and a whole spectrum of other
10 possibilities, some of which are quite unlikely but much
11 more serious than steam generator tube leakage.
12 I think we will cover both main steam line break
13 with leakage and main steam line break with tube ruptures,
14 in fact, multiple tube ruptures will cover all those cases,
15 but the more extreme cases we'll discuss this afternoon.
16 The other issue that I would like to make sure the
17 committee understands is on the viewgraph it said that Dr.
18 Parry would be here this morning, but in fact he will be
19 here this afternoon to talk about operator action and human
20 reliability analysis in the context of the severe accident
21 issues and if we have design basis human reliability
22 questions, which I think are very limited conceptually, I'll
23 either try to cover them this morning or relate those to
24 this afternoon's discussions.
25 CHAIRMAN POWERS: I think the issues of human

1 actions during design basis accidents are raised by the
2 statement of considerations where there is a phrase in
3 considerations that I am sure I can't quote accurately from
4 memory but it is to the effect that provided several key
5 operator actions are carried out, and I think that is mostly
6 controlling the usage of water during the accident, and what
7 happens it seems to me is the time available for making
8 those key operator actions can shrink under some of the
9 higher leakage assumptions associated with main steam line
10 break, so I think it's just a matter of understanding how
11 one decides that one can credit operator actions in light of
12 the time available.
13 That has been an area of some contention for some
14 period of time.
15 MR. HOLAHAN: The distinction that I would like to
16 make is in the design basis accident context those operator
17 actions are targeted to keeping the event within the dose
18 guidelines of Part 100 and so forth. Tube ruptures -- that
19 means isolating the leak. For steam line break I guess it
20 relates to the cooldown.
21 In the severe accident context the operator
22 actions are preventing core damage and so there are a
23 different set of considerations. As we go along we may pick
24 those out, but when they look like core damage issues I am
25 going to push them off until this afternoon.

1 DR. BONACA: One note however. Although the
2 design basis has the objectives you stated, the ERGs, which
3 are the emergency procedures that currently the Westinghouse
4 operators follow has consideration of steam line break with
5 consequential failures of tubes or depressurization of the
6 secondary side too.
7 I think it is important that in that context if
8 there is an opportunity we discuss those kinds of procedures
9 because clearly the operators are being trained for
10 scenarios which are not part of the design basis strictly or
11 the severe accidents. They are trained for intermediate
12 situations where in fact you have to bring the system down
13 to RHR and they are being trained to do that both looking
14 for a subcooled condition to enter the RHR or even in a
15 saturated condition, which means or implies a very large
16 break and opening to the secondary side.
17 I think at some point, and I don't know if we have
18 any expertise on the ERGs, but that would be valuable for us
19 to understand how they support the human reliability
20 analysis that is presented in the NUREGs.
21 MR. LONG: I'd just thank the whole group for
22 presenting the first slide. My name is Steve Long.
23 [Laughter.]
24 MR. LONG: We want to rearrange the order a little
25 bit here. Joe Donoghue would be up next to talk about the

1 ability of thermal hydraulic codes and then I would be up to
2 talk about the equilibrium between ECCS flow and leak flow,
3 and then we have deferred the next issue, on operator
4 actions, to this afternoon, and then Joe Donoghue would be
5 up again.
6 We have decided to simply this process.
7 I will go through the description of the
8 relationship between the flow from the ECCS system and the
9 flow out the leaks and then we will let Joe do the rest of
10 the subjects this morning.
11 The first thing, I think it is important to
12 understand the intent of the review that we did in NUREG
13 1477.
14 MR. HIGGINS: Steve, before you get off into that
15 detail, I had just one additional clarification on design
16 basis versus the other things.
17 Yesterday we talked a little bit about whether or
18 not this Generic Letter 9505 with the alternate repair
19 criteria and the analyses associated with that really
20 constituted a new design basis accident, new design basis
21 event.
22 I guess I am still not clear whether you consider
23 that that is or not or you are just changing the analysis
24 method but you don't really call that a new and different
25 design basis accident?

1 MR. HOLAHAN: I would call it the same design
2 basis accident with -- the only thing that is substantially
3 different is the main steam line break, instead of having a
4 1 GPM leak now has leakage based on the likelihood of a
5 number of cracks opening, so I would say it is the same
6 design basis event with a different set of assumptions -- so
7 it is main steam line break with leakage and a calculation
8 done to show that it means the Part 100 guidelines.
9 That analysis is part of the design basis. It is
10 part of the licensing basis, because, you know, a license
11 amendment ends up described in the FSAR just like the
12 original 1 GPM case.
13 MR. HIGGINS: Thank you.
14 MR. LONG: To try to draw that out a little bit
15 further, first of all, this was done before risk informed
16 regulation.
17 The intent is to not apply this type of permission
18 to leave a particular type of flaws in service to anything
19 other than what we expect is going to be a confined area of
20 the tubes within drilled hole tube support plates.
21 It doesn't apply to egg crates. It doesn't apply
22 to free span.
23 There's a problem with analyzing exactly how the
24 tube support plate would behave during a main steam line
25 break, so on the one hand, there is an effort to act as if

1 the tube support plate were to completely move off the
2 flawed portion of the tube and Generic Letter 9505 requires
3 that the probability of those flaw rupturing be small and
4 that the amount of leakage that would come out of those
5 flaws be such that you could still meet the Part 100 part of
6 the regulation.
7 So, as Gary said, we are not supposed to have a
8 steam generator tube rupture as a result of a main steam
9 line break, and the specification there was that the
10 probability not be greater than, the conditional probability
11 not be greater than .01.
12 Is that a new accident or is it a specification of
13 how improbable it has to be that there is a new accident?
14 You can, I guess, take your pick on your
15 interpretation of that, but I think the intent there was
16 really to try to keep within the guidance that we had for
17 having a low probability of failure under design basis
18 accidents and leakage that was within the guidelines for
19 design basis accident for dose from design basis accidents.
20 On the other hand, there was at the same time a
21 feeling that you would most probably have the tube support
22 plates actually confined to those portions of the tubes that
23 were degraded, so when we looked at it from a risk
24 standpoint we did not see a high probability of something
25 that would move the plates off, so at the time we did NUREG

1 1477 we really didn't have a risk assessment in 1477. The
2 risk assessment is counting on the plates remaining in a
3 position that confines the crack sufficiently.
4 That has been a difficulty for us in dealing with
5 the industry because the industry is frequently saying,
6 well, we analyze these cracks as if they were in the free
7 span; why can't we have permission to have them in the free
8 span? That brings up a bunch of issues that we really
9 didn't deal with because we were relying on them not being
10 in the free span, and we will get into some of those issues
11 this afternoon.
12 It gets a little difficult when we use shorthand
13 in terms of whether or not something is a design basis
14 accident or a severe accident. There's different uses of
15 those words and different groups of jargon and it is often
16 allowing you to make an erroneous leap into something not
17 intended, and we will just have to keep reeling those in if
18 they get made throughout the rest of the conversations.
19 Are we ready to go for the next slide, next
20 subject?
21 The committee asked for a justification of the
22 assumption that the maximum leakage rate would reach an
23 equilibrium with the injection flow during the main steam
24 line break that induced tube leakage.
25 The explanation for this has to go back to the

1 context in which the assumption was made. The original DPV
2 document indicated that there might be a problem with not
3 being able to detect flaws that were more than 40 percent
4 through-wall and therefore it requested that licensees
5 either abide by the 40 percent through-wall criteria or in
6 some way demonstrate that they could meet a main steam line
7 break with 80 percent of the tubes ruptured.
8 That was dealt with by the Office of Research for
9 awhile, trying to figure out how many flaws might go
10 undetected in the free span and how many of them might leak,
11 how much they might leak, and some efforts were made based
12 on some assumptions about flaw growth rate to determine what
13 amount of leakage rate could exist under these
14 circumstances, and the numbers were quite high. They went
15 up around 10,000 GPM for a large number of flaws with large
16 growth rates.
17 That was the point at which we picked this up.
18 We were trying to put it into a context where we
19 could start thinking about the risk.
20 The difficulty was trying to figure out how you
21 would get that much of a flow rate, because if you can
22 somehow break the flaws that much you are well down into the
23 LPSI injection path that is essentially a large LOCA outside
24 containment.
25 Without going into human errors or human success

1 probability and dealing with large LOCAs outside
2 containment, I just want to go to the justification of the
3 assumption that you asked about.
4 And it basically goes to the thermal hydraulics of
5 a main steam line break, and I'm just going to put up a
6 sketch because the things that are available as graphs
7 didn't show very well, and I hope this shows.
8 Okay, if you look at what happens as a function of
9 time to the pressure in the RCS and the pressure in the
10 steam generator, when you break open the steam generator,
11 the fluid in the steam generator is at saturation, so it
12 doesn't just drop as if it's sub-cooled with a little bit of
13 cover gas.
14 It evaporates; it boils, so it holds pressure up
15 until it cools itself by boiling and it depletes.
16 And that cooling brings down the RCS pressure
17 along with it, so that the differential pressure in this
18 part really stays approximately the same until you've really
19 stopped the cooldown process.
20 At that point, you've tripped your reactor coolant
21 pumps, but you still have decay heat. But the major
22 repressurization process is that you're pumping in emergency
23 core cooling water, and you may be trying to turn on heaters
24 in the pressurizer when you get level back to where you can
25 heat something.

1 So, at some point, you start getting a higher
2 delta-P. And it progresses in a reasonably quick manner,
3 but not an instantaneous manner, to a higher delta-P.
4 The question was, what would happen in the cracks
5 under this kind of a scenario? And neglecting the idea that
6 there are cracks and they might open for a minute, just
7 thinking about if there was a hole that suddenly appeared at
8 this point, it's very similar to a LOCA in the sense that
9 you're trying to pump water in and the leak is removing
10 water.
11 So you have a curve for the leak rate that's a
12 function of the pressure that's driving water out of the
13 leak, and you also have a function for the amount of water
14 that can be put in by the centrifugal ECCS pumps.
15 So, at low pressure, the leak is not going to be
16 putting out much and the pump is quite capable of pumping in
17 a lot of water, and as the pressure goes up, the pump is
18 going to be going to less and less input, and the leak is
19 going to have more and more driving force at the fixed area
20 hole.
21 So typically for LOCA analysis, you get to
22 whatever this pressure is, and it equilibrates there, at
23 least temporarily until you change something else in the
24 RCS.
25 So that's the kind of thought process that I want

1 to go to, but then I want to add the idea that the cracks
2 start with a very small hole and are increasing that hole
3 size.
4 So this is now not this curve, but as you increase
5 the pressure, you may be doing something like this as you
6 make the hole larger, as well as make the pressure greater
7 for driving fluid through those holes.
8 If you're starting off at a delta-P that's very
9 similar to what has been experienced for a long period
10 during operations, you know that the holes aren't opening up
11 very rapidly there.
12 However, the tests that have been done at the
13 National Labs, where they have taken cracked tubes, put them
14 into a test apparatus and stepped up the pressure, and had
15 hold times in the pressure inside the tube, have shown cases
16 where the tube may sit at a constant pressure without
17 leaking, and then suddenly without increasing the pressure,
18 it will start to leak, something will actually let go and
19 the leak will occur.
20 Or you may find that something that is already
21 leaking and is being held at constant pressure, will slowly
22 increase leak rate or maybe it will make steps in leak rate.
23 Now, we've seen all of these things occur. These
24 are happening, though, at small leak rates, and the leak
25 rates are staying small for one particular crack. It's not

1 a rupture, it's just a change in the crack opening area that
2 may not be a single value as a function of pressure.
3 And I think this is one of the major points in the
4 DPO.
5 And we tried to put that in the context of the
6 scenario where the delta-P in the reactor coolant system is
7 increasing, and we are envisioning a very large number of
8 cracks.
9 What we were envisioning was that these cracks
10 would not all behave in unison, so that if one of them would
11 pop, every one of them would pop at exactly the same moment.
12 And the wording is down here in the slides, but
13 rather than put it up and read it to you, let me just try to
14 talk my way through it.
15 The picture I was trying to come up with is
16 something that would tell me how far I could expect to open
17 the cracks before I'd really lose the driving force for
18 opening them any more.
19 And the logic was this: That if your delta-P is
20 going up in time from a value where essentially there
21 weren't any cracks open, and cracks begin to open, that the
22 delta-P is going up because you're putting water into the
23 system.
24 And as you open more cracks, you're removing more
25 water, and eventually you should reach an equilibrium

similar to what's going on here, but not necessarily at the original hole size. You're increasing this curve just more rapidly.

So you'd eventually come to some equilibrium point higher than your normal delta-P across the steam generator tubes, where you're putting water out at the same rate that the ECCS pumps can put water in.

Okay, still, that's a constant pressure differential higher then they have been experiencing before. Maybe they can continue to pop and tear open a little bit further.

So for that process, again, if you increase the area more, you raise the curve up, so it's now running up here, rather than down there.

The pressure drops, more water comes in from the ECCS system, and you can envision that perhaps reaching a point where so many things have opened up that you've gotten all the way back down to the normal delta-P, in other words, you now have essentially zero pressure on the secondary side, your reactor coolant system is now at a pressure that was equivalent to the pressure difference between the steam generator and the RCS previously.

At that point, we didn't see any reason to open up the cracks any further. They were stable at that point.

Usually in the laboratory, if you've pumped a

1 crack to the point where it starts to leak, and you drop the
2 pressure substantially, the crack pretty well stabilizes; it
3 doesn't continue to come apart, unless you've lowered the
4 peak pressure differential that it's in.
5 So the argument is essentially that we don't see
6 any mechanism for the delta-P in the system to open cracks
7 beyond the point that the ECCS pump could support when the
8 ECCS pump back pressure is equal to the original steam
9 generator delta-P.
10 CHAIRMAN POWERS: But this is a conclusion one
11 raises because you're looking at a very quiescent system?
12 MR. LONG: There's --
13 CHAIRMAN POWERS: When we look at a system that's
14 producing sonic booms and pressure pulses and things like
15 that, maybe those arguments aren't so strongly made.
16 MR. LONG: Okay, well, first of all, the sonic
17 booms and so on should be stopping in time, somewhere down
18 in here. So in terms of timing, we're not expecting that to
19 necessarily be concurrent with what I was just talking
20 about.
21 So the limitation on this is, if during this part
22 of the process here, you're talking about the new generic
23 issue designation that cracks that have been initiated as
24 stress corrosion cracks, are now being fatigued by
25 vibration, that's a different phenomenon.

1 And the thing you've asked me to justify was not
2 intended to try to cover that kind of phenomenon.
3 Now, earlier on in the process, when we were doing
4 NUREG 1477, I was talking to Joe Hopenfeld about this and
5 some other things, and he was discussing vibration as being
6 one thing that would open them.
7 At least insofar as I was hearing it, I was
8 hearing it as vibration being able to shake the plugs out of
9 cracks that were plugged with crud or something of that
10 sort, as opposed to the fatiguing issue.
11 So to some -- let me just finish the sentence. To
12 some degree, if you're dealing with cracks that are not
13 being increased in size, you can go up into this section of
14 the curve and say, well, if I'm starting to leak here, then
15 what I'm going to do is drop this pressure even faster on
16 the RCS.
17 And I'll be dropping my strain again. The
18 difficulty we had was we didn't have a mechanism that we
19 could use to show us how much we could open these tubes,
20 other than the strain from the pressure.
21 We talked about things, and I think a lot of
22 people in this room had to put up with me asking them
23 questions about if we had a large number of cert cracks and
24 there was a displacement by the upward force, can you
25 essentially pull apart a large number of cert cracks?

1 We were looking for things that weren't
2 self-limiting in some way, but we didn't find something that
3 we could physically credit and put a conditional probability
4 to and put into a risk assessment.
5 So, essentially, this is the description of what
6 we were thinking of the time, and what we think it was good
7 for and what we think it wasn't good for.
8 I'll answer questions on that and turn it over to
9 Joe Donoghue.
10 DR. HOPENFELD: I have a minor comment. In that
11 original document, there was a description of that droplet
12 eating the adjacent tubes, if you remember.
13 MR. LONG: That's also true, and we at that point
14 were not thinking about the droplets eroding the tubes under
15 main steam line conditions.
16 We were worried about it under hotter temperature
17 conditions. And so we weren't crediting that one, either,
18 for this particular analysis.
19 MR. STROSNIDER: Steve, this is Jack Strosnider.
20 For the system response that you're talking about
21 here, does it really matter how the leakage -- where it
22 comes from?
23 I mean, you were talking about assuming that
24 there's a hole and that there is some leakage, right. And
25 this idea of the system equilibrating at some point, does it

1 matter if it comes from 9505 leaks or if it comes from
2 hyperation or anything else, right?
3 I think you were trying to address the issue more
4 of a system response to a leak; that's the point.
5 MR. LONG: Well, there is a difference. If the
6 only thing that's creating the additional leakage is the
7 additional delta-P, then what the tubes have demonstrated is
8 an ability to survive that for a long period of time.
9 If there's no other driving mechanism besides that
10 elevated delta-P, you can make this limitation and say if
11 it's your ECCS pumps that are providing that delta-P, you
12 can follow your pump curve and figure out how much your flow
13 rate is going to be at worst, that you would have to deal
14 with, and how fast that will deplete the RWST and so on.
15 If you have something that's mechanically damaging
16 the tubes, even though it requires a delta-P to do it, it's
17 a new damage mechanism, you know, some sort of additional
18 tension or vibration or whatever that might, along with a
19 delta-P, create more damage to the tubes than they have been
20 seeing when they were in a quiescent condition at a delta-P.
21 You might break them open further, and you might
22 get more flow rate. You might go farther, but --
23 DR. CATTON: But that poor flow rate is still
24 going to be a function only of a delta-P. That's just that
25 it now is the square root of delta-P, and now it's going to

1 become maybe proportional to delta-P, because two things are
2 happening: The area is getting bigger, so it's just a more
3 complicated control valve; isn't it?
4 MR. LONG: It's more complicated than I predict a
5 limit on, is my point.
6 DR. CATTON: Still, if the pressure drops back
7 down, it's going to shut back down; it's going to slow down.
8 MR. LONG: If what you're doing is -- I'm
9 speculating here. If --
10 DR. CATTON: Well, I was, too.
11 MR. LONG: If you have fatigue cracks -- if you
12 have cracks that are growing by fatigue, you know, from the
13 vibration, and the fact that they're pressurized internally,
14 what's the limit on how much you can open cracks in the
15 system? How much delta-P do you need to keep opening the
16 cracks?
17 Just because you've gotten down to the delta-P
18 that they were stable at before you had the vibration,
19 doesn't mean that the with the vibration continuing, they
20 would remain stable under that condition.
21 DR. CATTON: So when you look at this curve,
22 wouldn't that just mean that you wind up staying down at the
23 bottom?
24 MR. LONG: You're saying that this winds up down
25 here?

1 DR. CATTON: The pressure doesn't go back up.
2 MR. LONG: Okay, but if you found that you've
3 leaked and then you go back up, then what you're really
4 saying is -- and there's still a delta-P along here that's
5 --
6 DR. CATTON: You empty your IWRST and you're in
7 trouble.
8 MR. LONG: Well, that's part of it, but I don't
9 think you can say you'd stay there.
10 If you had the same delta-P that you started with
11 or just a little bit more, and you're shaking the tubes.
12 DR. CATTON: The more open space you've got
13 between the two systems, the smaller that delta-P is going
14 to get.
15 MR. LONG: Right, so what you're really saying is
16 not that I get here, but that this comes down here.
17 DR. CATTON: That's right.
18 MR. LONG: That's my point. I don't know how low
19 to say this would go.
20 DR. CATTON: It depends on how big the area is.
21 If you make it big enough it will go all the way.
22 MR. LONG: It depends on how much damage you get
23 from the vibration. So my limitation on this is that I
24 can't say that the flow from ECCS pumps at a particular
25 value, which is this delta-P, is the maximum flow I expect

1 from the primary to the secondary.

2 I've got to take into account, the damage in some

3 other way, if that is the damage mechanism.

4 DR. BONACA: I have a question that I would like

5 to ask: It seems to me that we can argue about the damage

6 mechanism forever, because there is a position that says we

7 are going to have as much damage as you want and as much

8 leakage as you really can postulate on many tubes.

9 And there is a position they are presenting where

10 the leak is self-containing, and this must be a leak on the

11 order of one tube, maybe two tubes, because you're showing

12 pressure coming back up.

13 And if you had much substantial more failure

14 there, pressure would not come up, back again. I mean, it

15 would stabilize somewhere pretty low.

16 It seems to me that if we are trying to ask the

17 question, will the operator be able to deal with the

18 leakage, whatever leakage will come out, and what kind of

19 range for this kind of damage, it's such that the RWST will

20 not be emptied, and we will not come to a containment bypass

21 situation.

22 That's a central question, it seems to me, and so

23 the issue is have we looked at other flow rates that would

24 result from larger breaks or a larger number of breaks?

25 I mean, I have been reading a lot of these

1 reports, particularly NUREG 1477, and the INEL report, and
2 they seem to present a model where they have looked at up to
3 20 tubes failing.
4 So I would like to hear about that. I mean, if we
5 concentrate on the issue of will it happen or not happen,
6 we're going to be left with the dispute in place.
7 MR. LONG: One of the interesting things that
8 happens to me as I try to put all these things together into
9 a risk assessment is every time we run into one difficult
10 question, there is always the urge to bypass that question
11 by going to another area of study, and that turns out to
12 have a difficult question as well.
13 So if we assume that the flow rate will go to a
14 very large value, the other limit on that value that you can
15 postulate is essentially the size of a hole that is in the
16 main steamline as a flow restrictor, and that is a pipe
17 that, depending on the size of the plant, I understand is
18 from like nine to 16 inches in diameter, that would
19 basically run through the containment wall from a point that
20 is high up in the RCS.
21 We have thermal-hydraulic analyses that would
22 indicate how the plant system would behave under those
23 conditions and, essentially, it depressurizes quite rapidly.
24 It gets quite cool because you are doing a wonderful job of
25 cooling, and you are depleting the RWST very quickly.

1 If you look at the conditions, you are at RHR
2 entry conditions when you have a very massive leak like that
3 rupture. The question then becomes one of human error
4 probability, or even feasibility, if you look at the
5 guidelines. Can you actually turn on RHR under those
6 conditions? And it doesn't become just a matter of looking
7 at the procedures and the time available, you have to start
8 asking questions at this point about, well, where did all
9 that water go? If you have just emptied pretty much a steam
10 generator and the reactor, and two-thirds of your RWST out
11 into the plant somewhere, can you go turn on RHR? It
12 usually requires you to do something outside the control
13 room.
14 MR. HIGGINS: But, Steve, if we get into these
15 discussions now, haven't we left design basis accident space
16 and entered severe accident space?
17 MR. LONG: Yes. So, well, that is the --
18 MR. HIGGINS: And I didn't know if you had
19 transitioned in your presentation yet.
20 MR. LONG: That was the point, we are going to be
21 talking on the hairy edge the whole time for the rest of the
22 day, and I don't think we can just keep saying, well, that
23 is a severe accident, we will talk about it later. We have
24 to talk about the transition.
25 DR. BONACA: The reason why I asked you the

1 question, however, wasn't that I say that you have to
2 assume. We are trying to understand what are the
3 limitations of the combined power plant systems and operator
4 that will probably give us success up to a certain break
5 size. And then we will judge as reasonable people how
6 credible that size of rupture is going to be, and if it
7 bounds the concerns that have been expressed about damage,
8 or if it doesn't bound.
9 And, for example, one could say that if you
10 postulate a failure of 10 or 15 tubes, and you could make a
11 case where you can still give some success to the operator
12 in preventing the bypass, it would be more comforting than
13 saying that the operator cannot cope even with two tubes.
14 Okay. So I would like to just simply see if we can, at some
15 point, understand that, because I think that is an important
16 issue, and it tells us what we are dealing with insofar as
17 uncertainty.
18 MR. LONG: I think you are correct in wanting to
19 look at the human error probability part of this, and when
20 we get into the discussion later this afternoon, I will show
21 that I think that is an important aspect. I think it is a
22 dominant aspect for a lot of these things, not just the one
23 you are talking about now.
24 However, trying to use human error probability
25 calculations to narrow your focus for thermal-hydraulic

1 calculations doesn't -- usually it works the other way
2 around because we are a little more precise with the
3 thermal-hydraulics than they are with the human error
4 probabilities.
5 But it is a problem of can you get information
6 together to bound the issue or not, and it is a struggle
7 here. And one of the things I think you have to go back to
8 is, is there a credible method for making a large hole,
9 rather than just assuming a large hole? In the design
10 basis, we have chosen to assume large holes and required
11 licensees to do fairly significant demonstrations that they
12 can cope with those large holes in those places. But one of
13 the ones we never did require them to cope with is a large
14 hole that takes the RCS fluid to somewhere where it cannot
15 go into the recirc path, and that is something we have known
16 as a concern since the reactor safety study in the '70s.
17 I think one of the things you have to do in trying
18 to bound this whole question is approach all the pieces, not
19 just leave one go and try to do it with a few that remain.
20 And I think you have to look at, what do we think we can
21 really expect to get in the way of a hole size? What is
22 credible? Because if it is really a credible hole that we
23 haven't considered before, maybe we need to change the
24 design basis to include it.
25 On the other hand, when you get into risk, if you

1 think it is plausible, but not really high probability, you
2 may be able to handle, put in some of the rest of the
3 features and decide that the risk is low enough overall to
4 not have to go any further in the analysis. A risk model
5 does not define all things to a fine degree, a risk model
6 usually goes as far as you need to go to make a decision and
7 stops, hopefully, just a little bit beyond there, as opposed
8 to just short of there, to support the decision. And it is
9 hard enough to get to that point.
10 MR. HOLAHAN: Let me come back a bit. We are
11 talking about design basis, we are not speculating about
12 some, you know, future design basis. What we are talking
13 about is design basis, you know, as it is allowed in 95-05
14 or other situations, and none of these cases allow main
15 steamline break with tube ruptures. Okay.
16 We are talking about leakage rates, you know, a
17 few GPM may be 100 GPM. That is why these cases look like
18 repressurizations, okay. In the severe accident analysis, I
19 keep coming back to saying we will discuss it this
20 afternoon, we looked at single and multiple tube ruptures,
21 okay. We have not decided that those should be part of the
22 design basis. In fact, I think we will never probably
23 decide those should be part of the design basis, because we
24 probably don't want those to be likely enough to be
25 considered part of the design basis. We would like to

1 preclude tube ruptures, and, certainly, multiple tube
2 ruptures, given a main steamline break.
3 The fact that we analyzed them doesn't mean that
4 we want them in the design basis. You know, we analyze
5 things beyond the design basis, that is what severe accident
6 risk analysis is about.
7 So I think you need to think of this design basis
8 discussion in the context of relatively small leaks. The
9 original design basis for a long time was like 1 GPM. Now,
10 we are talking about 95-05 having cracks open up and, in
11 fact, probably at very small leakages, but because we can't
12 really analyze those and assure that the leakages are very
13 small, you know, we look at them as though they are freespan
14 cracks and they are not confined and all of that. But these
15 are still leakages of a few GPM, 10 GPM, 30 GPM, you know,
16 in some of the more extreme cases, maybe up to 100 GPM, but
17 none of them looks like a tube rupture.
18 DR. CATTON: What about tube rupture with a stuck
19 open relief valve? This is kind of similar, your mild
20 steamline break where nothing much happens. How different
21 is it? There you are going to have your 600 GPM and you are
22 going to have it open to the atmosphere.
23 MR. HOLAHAN: And, in fact, we analyzed those as
24 some of the more likely severe accident challenges, but
25 those are not in the design basis either.

1 DR. CATTON: You mean the steam generator tube
2 rupture was an open relief value, was not --
3 MR. HOLAHAN: It was not in the design basis.
4 DR. CATTON: But that happened, that has happened.
5 Didn't it happen at Ginna?
6 MR. HOLAHAN: No.
7 SPEAKER: I think they were able to close the
8 relief value.
9 MR. HOLAHAN: The main -- the safety valve on the
10 steam generator leaked for some continued period of time,
11 but it didn't stick open.
12 DR. CATTON: Pretty close.
13 MR. HOLAHAN: I spent three weeks in snowy
14 Rochester checking out that particular issue in 1982, and
15 the valve was pretty well seated but leaking.
16 MR. LONG: A lot of the plants have a requirement
17 for being able, with a single failure, to prevent overfill
18 of the steam generator. Now, there is a human error
19 associated with not succeeding in doing that. So when we
20 look at the severe accidents, that is included as a
21 scenario.
22 It is more a matter of how many tubes do you have
23 ruptured.
24 DR. CATTON: No, I understand that. I understand
25 that. I just thought maybe you were part-way there.

1 DR. BONACA: Just to complete my thought, however,
2 since we had it, I agree that there is a design basis issue
3 and there is a severe accident issue. But I see two
4 different types of severe accident issues. One is one where
5 you have a severe accident like a station blackout, and then
6 you are questioning whether or not the surge line or the
7 tubes will fail first.
8 Now, there is nothing the operator can do about
9 that issue at that point.
10 MR. HOLAHAN: Well, in fact, --
11 DR. BONACA: Let me just finish.
12 MR. HOLAHAN: Go ahead.
13 DR. BONACA: The other is the scenario where I
14 have a steamline break, which may happen, and I may have
15 tubes failing that may be beyond the design basis and I
16 ignore that. And we are training the operators right now to
17 operate with ERGs with very specific directions, scenarios
18 where you have steamline break and tube failures, okay.
19 There is a full range of analysis being performed behind. I
20 am trying to understand how credible that is, because this
21 is a more significant issue in my mind.
22 We have operators who are now in the control room
23 trusting that the ERGs will lead them some success under
24 this kind of condition. That is why I am introducing, I
25 guess, a third kind of scenario in between, is the one where

1 you have a design basis moving into a severe accident, but
2 you have a full body of license documents, I don't know how
3 licensed the ERGs are, but they are certainly used there,
4 that at least pretend to be able to cope with those
5 scenarios.
6 And that is why I am trying to understand, you
7 know, as part of this presentation today, how these ERGs can
8 or cannot be successful.
9 MR. HOLAHAN: And have analyzed both types of
10 those issues, both -- what we call the high dry sequences,
11 core damage leading to tube failure, and, also, what would
12 start out as a traditional design basis event and then
13 exceeding the design basis conditions and going to core
14 damage.
15 In the context of design basis versus severe
16 accidents, we call both of those examples severe accident
17 cases, okay, because you won't find either of them in FSAR.
18 DR. KRESS: Gary, let's pretend that we were back
19 in the Dark Ages where all we had was design basis and
20 didn't have risk and severe accidents, except we kind of had
21 them in the back of our mind. We defined these design bases
22 as in terms of probably some perceived frequency at which
23 they might occur.
24 MR. HOLAHAN: Yes.
25 DR. KRESS: But looking at the design basis of,

1 say, a main steamline break, we had specified in that design
2 basis, that it leak at the tech spec leak rate.
3 Now, the reason that specification was in there,
4 though, was because we had another something in the rules
5 that said you will not exceed -- cracks that are more than
6 40 percent throughwall you will plug. Now we are talking
7 about changing that part of the rules, and we don't have
8 anything about risk and stuff in there, but we change one
9 part of the rule, it seems to me like we have already
10 changed the design basis accident. And you may have changed
11 it to the point where you might have to talk about changing
12 the leak rate. And if you change it enough, you might have
13 to talk about an induced steam generator tube rupture.
14 It seems to me like we already changed the design
15 basis accident, and the question is, how much are we going
16 to change it?
17 MR. HOLAHAN: Well, I agree that if, in fact, we
18 were to allow leak rates sufficiently large so that the
19 events don't look like -- it doesn't look like a main
20 steamline break, it looks like a much more complicated
21 event, it looks like a steamline break and a tube rupture,
22 or it looks like a small LOCA, then, in fact, we would be
23 having a different event.
24 But we are not talking about allowing such
25 leakages. And I don't think we want to go there.

1 DR. KRESS: Okay. But what I thought was, if you
2 change the rules about how you deal with the steam generator
3 tubes, it might very well be that you have no control over
4 what leakage you are allowing.
5 MR. HOLAHAN: No, no. I think, in effect, what we
6 have done is very carefully, in 95-05, looked at the
7 increased leakage implications associated with change.
8 DR. KRESS: You say there is now another part of
9 the rule that does give you a reason to specify a leak rate
10 as part of the design basis.
11 MR. HOLAHAN: Yeah. And I think that is part of
12 what you heard for the last day or so, is that the dose
13 calculations -- and as early as Jack Hayes' calculations
14 from yesterday, the dose calculations are done with
15 substantially higher leak rates for a plant that is using a
16 95-05 process. But we are not allowing those leak rates to
17 be sufficiently high that, in fact, they were creating
18 different accidents.
19 DR. KRESS: Not allowing them under -- at some
20 frequency.
21 MR. HOLAHAN: Not allowing them as expected
22 results.
23 DR. KRESS: Expected results.
24 MR. HOLAHAN: As an expected part of the design
25 basis.

1 MR. LONG: You put your finger on one point, and
2 that is that, initially, there was no understanding of a
3 difference between the normal operational leakage from the
4 steam generators and the accident leakage. People weren't
5 thinking cracks that would open. They were thinking tubes
6 that could only stand about 10,000 psi, and they might have
7 pinholes or there would be wastage that you checked and you
8 patched before it got less than 4,000 psi in strength.
9 And when we divorced the accident leakage from the
10 operational leakage, the accident leakage doesn't appear in
11 the tech specs now, it is a value that is put into the
12 Chapter 15 analysis. So what is happening is people are
13 lowering what is in the tech specs, which is the iodine
14 concentration and the coolant and then through the Chapter
15 15 analysis, they are increasing the leak rate.
16 There is no real limit on how far that leak rate
17 can go. You know, if they are operating at 10 to the minus
18 4th mikes per cc, and the limit, the assumption is 1, and
19 the Chapter 15 analysis for 1 GPM, and they are still not at
20 30 rem to the thyroid in the control room, you know, you can
21 get the leak rate up to 10,000 GPM and still meet Part 100.
22 So what Gary is saying is, well, when we grant
23 these things, we are granting them on a case by case review
24 and we don't intend to grant something with that high a leak
25 rate. We have gotten up to 132 in Byron 1 at least, I don't

1 know about Braidwood, for one cycle, or the last part of one
2 cycle. I was nervous when we got to 132, and I wanted to
3 ask, what do we think the real leak rate is if these cracks
4 are, you know, contained in crud-encrusted tube support
5 plates? Especially if you shake those tube support plates
6 with a main steamline break.
7 We know that the French have done some studies.
8 You asked about the crud. The French have done some studies
9 where they have harvested tubes with the support plates
10 intact, drilled a hole through the support plate, the crud
11 on the tube, and plugged the support plate. So what they
12 have is an opening into the crud. And they have
13 demonstrated it is pretty tight until you move the support
14 plate with respect to the tube some distance, and then
15 apparently you crack the crud and you do get some flow. It
16 is still nothing like the leak rate that you would get if
17 that hole was in the freespan.
18 And, in addition, it is a hole you drilled. If it
19 was a crack and it was essentially in a tube that was being
20 dented, and that is the reason you had the crack, the crack
21 may not be able to open and create that hole.
22 So we don't really have a way of calculating the
23 leakage as long as that crack remains within the tube
24 support plate. But we are counting on it being lower than
25 the value we calculate as if it is in the freespan. And

1 there is not a very strong knowledge base to tell us how far
2 we can go in this pseudo leak rate in the Chapter 15
3 analysis.
4 CHAIRMAN POWERS: Do you have the description of
5 these?
6 MR. LONG: If Emmett Murphy was here, I'd be glad
7 to say yes, but I'm not sure I know of anybody else in the
8 audience that has them right now.
9 We'll try to make sure we get them for you.
10 MR. HIGGINS: Steve, most of the discussions we've
11 been having relate to the main steam line break and then
12 what happens with the possibly-induced leakages.
13 If you use the stuck-open relief valve as another
14 initiator, rather than the main steam line break, does the
15 main steam line break bound that, or do you need to
16 separately look at the stuck-open steam generator relief?
17 MR. LONG: When you say bounded, in what sense?
18 MR. HIGGINS: That you don't need to look at that
19 and analyze that separately.
20 MR. LONG: Well, when you get into the accident
21 sequences and event tree, they're different.
22 MR. HIGGINS: I'm talking design basis.
23 MR. LONG: Well, this is what I mean by in what
24 sense? If you're asking, do you get the same kind of
25 vibration in the tubes when you use blowdown to a stuck-open

1 safety valve, I don't think you get that.

2 The repressurization is slower. We've done it a

3 few times already.

4 I would expect that to be a more benign problem

5 from the standpoint of the blowdown effect.

6 On the ohter hand, it's something where -- I've

7 taken the graph down now, but it's something where the

8 operators have had a tendency to repressurize the system and

9 increase the delta-P.

10 MR. HOLAHAN: In the context of the question, the

11 design basis, the question is, would it produce higher doses

12 in design basis?

13 MR. LONG: That's the reason I asked in what

14 context.

15 You're saying -- if the question is, would the

16 doses be higher or lower --

17 MR. HOLAHAN: Than a main steam line break.

18 MR. LONG: Probably, I think they would calculate

19 in as the same in a design basis. I think they'd just

20 assume that the secondary side is open to the environment.

21 They would assume that the secondary side is

22 voided, is depressurized, so there's no scrubbing. And I

23 would assume they'd get the same answer.

24 I don't think they have gone into the physics in

25 any greater detail.

1 DR. HOPENFELD: Can I make one comment? Is that
2 okay with you, Steve?
3 MR. LONG: Sure.
4 DR. HOPENFELD: I'd just like to put it in
5 context. And what Mr. Holohan said is very true, that 9505
6 is limited to very small leakages.
7 In fact, that was really the main reason why I
8 converted that DPV to a DPO in July of '94, just before that
9 9505 went on the street.
10 And if I remember correctly, I had a discussion
11 there, and I said, well, anything below 100 or 200 gpm is
12 not of concern to me, because the operator will take care of
13 that.
14 The whole issue was, what we're doing is just as
15 you describe now, but look what happened. We were 94 and we
16 basically accepted htat idea that we don't have to go beyond
17 these small leakages.
18 And so we have the six years of all that time
19 that, you know, that we sort of accepted it, and we haven't
20 -- and that's really the main issue here, why -- I think
21 we're focusing on it, and that's why 9505 is not adequate.
22 But we accepted it and let it stay there, and then
23 we say it is adequate and we're ruling out any leakages
24 beyond one gpm or ten gmp, and I think you focused the
25 discussion as to where we should be heading with this.

1 MR. HOLAHAN: Let me comment on that, because I
2 think what it says is, the staff's intent is consistent with
3 Dr. Hopefeld's views; that is, that we both want to keep any
4 leakages, you know, following a steam line break, to be
5 small values which can be shown to be things that operators
6 can handle and are within the dose limits.
7 It seems to me that the disagreement is with
8 whetehr, in fact, the thigns that staff has done have
9 accomplished that goal.
10 MR. LONG: Yes.
11 MR. HIGGINS: Related to that, and the operator
12 actions, as part of the GL 95-05 reviews, were there any
13 reviews done to see if there were -- that the operators
14 could still handle the differences in the accident scenarios
15 between the one gpm leak and now, say, a 100 gpm leak after
16 the main steam line break, and verifying that the procedures
17 and the training and so forth were needed -- whether they
18 needed to be changed or not, or whether any other actions
19 had to be taken at the sites that are now operating under
20 these new tech specs?
21 MR. LONG: Okay, I'm not sure if Joe is going to
22 get into any of this. He's shaking his head, no.
23 MR. DONOGHUE: This is Joe Donoghue. I'll be
24 talking a little bit about this, but the short answer, I
25 think, is, there were no specific anlayses done fro the

1 licensing actions. We were depending on the 1477 and the
2 other analyses that I will talk about.
3 The conclusoins there convinced us that we didn't
4 need to do more work on a site-specific basis.
5 MR. LONG: Were you asking site-specific or just
6 were there studies done?
7 MR. HIGGINS: No, whether or not you needed to do
8 anything site-specific for the plants that were getting
9 these tech spec amendments, in order to ensure that their
10 procedures and training were capable of handling these
11 somewhat different design basis accidents.
12 MR. LONG: I don't believe we did that.
13 MR. DONOGHUE: I think the answer, again, is that
14 some of the anlayses that I will talk about were based on at
15 least one plant, because that's all we analyzed during the
16 rulemaking.
17 We used their procedures as the basis for the
18 actions and the timing.
19 That was a very brief synopsis of what was done
20 but our conclusions were that overall the licensee's
21 approach here was conservative.
22 They tried to make sure they were calculating what
23 would happen -- they used the condition that would give them
24 the highest peak loads across the tube support plates. To
25 apply those peak loads to all the tube support plates in the

1 generator when they took the next step to do the deflection
2 analysis and they applied a safety factor to those loads
3 when they did that deflection analysis.
4 From that we documented in the safety evaluation
5 that we considered what they had done for this license
6 amendment was reasonable. However, we made clear that this
7 was not a generically acceptable approach because of the
8 limitations MB-2 data. We didn't see this as a basis for a
9 qualification of this method for generic use.
10 About six months later I think I was one of the
11 people here again talking about this license amendment and I
12 think a subcommittee of the ACRS had some comments about it,
13 had some additional questions that came up on the ability to
14 model the flows in the generator during the main steam line
15 break and we have since used those kinds of questions to
16 supplement instances where we have addressed licensees
17 approaching us with this kind of request since then.
18 I can think of a couple of instances where we have
19 had very detailed discussions with licensees who have tried
20 to pick up the methodology that was used for Byron and
21 Braidwood and we have asked additional questions based on
22 what we got out of this June meeting and other things that
23 have come up since then and so far I don't know of any other
24 licensees that have been able to apply this sort of a
25 process, this modeling and methodology.

1 MR. CATTON: One of the problems is that it is a
2 nonequilibrium behavior. If you think about what happens
3 before any strong flow starts, the pressure drops, then you
4 convert to steam and you begin to build up the flow, and
5 this sort of starts from the bottom to the end so you can
6 wind up choking and unchoking.
7 This was the same thing that happens when people
8 considered the internal loads on the reactor following a
9 break. You get an expansion wave that travels inside. It's
10 nonequilibrium. What begins to bring it to a stable process
11 is when the nonequilibrium process is over and you start
12 just converting pressure into superheat and to steam and it
13 is steady.
14 The loads are going to be quite different. I
15 think it is the choking and unchoking that is going to get
16 you, and that is a very quick process at the beginning.
17 Of course it depends on how many of these area
18 restrictions you have from one end of this device to the
19 other, and somehow I was a member of the committee in June
20 and I don't remember the meeting but I guess if there was
21 criticism of it, it was probably me.
22 MR. DONOGHUE: I definitely remember your
23 questions.
24 [Laughter.]
25 MR. DONOGHUE: Scars --

1 MR. CATTON: It is not clear to me that you can
2 solve it as essentially an equilibrium process, it's not.
3 It's nonequilibrium and it's the nonequilibrium effects that
4 are going to lead to the difficulties.
5 You have to include them if you want to do it
6 properly and I don't remember the MB test either. I don't
7 know what the internals of that thing looked like.
8 MR. HOPENFELD: Can I just make a comment on that?
9 We had so many subjects the other day, but I did cover that.
10 The instrumentation was part of it about the peak
11 pressure, but that wasn't the main thing.
12 Remember, I showed you that the volume, the vessel
13 that was surrounding that slide of tubes, it was a factor of
14 six or seven higher than the volume occupied by the bundle,
15 so the whole flow phenomena was controlled but something had
16 to do with the flow in the tubes, and that was my point,
17 that you couldn't possibly benchmark RELAP against that kind
18 of data. It wasn't designed for it.
19 That was the point and I showed you in the
20 presentation the volume ratio and I think it is in your
21 handouts.
22 MR. DONOGHUE: One thing I remember we did say in
23 the safety evaluation was that it seemed reasonable to us
24 that there were so many impediments to pressure waves making
25 it back to the tube support plates because of equipment that

1 is in the steam generator that compared to the MB-2 setup we
2 thought, it seemed reasonable to assume that a lot of those
3 loads were not going to be any bigger or much bigger or some
4 phraseology like that than the differential pressures that
5 were trying to be predicted.
6 MR. HOPENFELD: There is actually no reason to
7 assume that.
8 MR. DONOGHUE: Well, that is assumption we made.
9 I am just stating what we documented.
10 I agree, you know, the question about the
11 equilibrium/nonequilibrium choice for use of RELAP was a big
12 issue and we --
13 MR. CATTON: Some of those pressure spikes might
14 be real. They tried a long time ago with Semiscale, one of
15 the Semiscale these they begin to get these big oscillations
16 and they tried to use all of the different codes and they
17 never could reproduce them.
18 The problem is when the pressure goes up, you are
19 condensing. When the pressure goes down you are
20 evaporating. The thing acts like this huge volume so all of
21 the frequencies are different. Everything changes.
22 MR. DONOGHUE: Let me step back for a minute to
23 again this discussion I tried to say was that -- I may be
24 able to state it more clearly now -- I am not here to try to
25 say that we have a basis for resolving the new GSI.

1 I am just here to say that this is some work that
2 the Staff is aware of that is connected to the issue and
3 this is as far as we have gone and we stated in the safety
4 evaluation there were clear limitations to what we were
5 doing and why we had problems with this when other licensees
6 have come in and tried to do this.
7 The technical details here, the ability to model
8 these things is certainly an issue and that's why I think we
9 put all those limitations on this when we first asserted
10 that.
11 I have no other information to present on this
12 topic. Refer back to, I think, material you have in your
13 truck-load of documents you have -- your safety evaluation
14 references what the licensee did and the safety evaluation
15 has the discussion about what the Staff did there and the
16 things I talked about here.
17 MR. HOLAHAN: I would just like to remind you that
18 this relates to something discussed yesterday, that the case
19 that the Staff approved was one in which because of
20 uncertainties and other issues we required the licensees
21 effectively to stake the support plate by tube expansions
22 above and below it so there was an additional basis for
23 saying the tube sheet wouldn't move, not just the thermal
24 hydraulic analysis, so you get an idea of the state of our
25 comfort and knowledge by the fact that we, even though maybe

1 your best judgment is that you wouldn't have a problem, we
2 didn't feel that the analysis without additional actions was
3 appropriate. Thank you.
4 MR. DONOGHUE: Yes, I tried to allude to
5 conservatisms and that is another one that I could have
6 added to the list.
7 If there are no other points to discuss, I will go
8 on to the next issue that I was asked to speak to you about,
9 which we have talked about to some extent already, how much
10 leakage can we -- do we think is tolerable during a beyond
11 design basis, even though I say during design basis
12 accident, we kind of call them beyond design basis events
13 here.
14 This is addressed in Issue 2 of the considerations
15 document. In there we talk about reports that have come up
16 repeatedly already and I will just summarize the first one,
17 NUREG-1477.
18 We have already talked about that so I won't spend
19 much time, except to say that there were calculations done
20 over a range of leak rates, primary-secondary leak rates,
21 and the conclusion there was that the RWST inventory could
22 be maintained in accordance, if the operators performed in
23 accordance with the emergency response guidelines.
24 The next report, and before I go into detail, I
25 will just try to put some context on this report, in 1993

1 when the rulemaking activity was begun, that's when the
2 Staff were brought together and told to charge off in the
3 direction of rulemaking, we were challenged by Mr. Thadani,
4 who was at that time the SSA Division Director, to try to
5 get a handle on where the risk significance lay here.
6 This was at the advent. We weren't really
7 risk-informing as much as we are trying to do today or in as
8 formal a manner as we are today, but he was very concerned
9 about these kind of events where we are going, pushing the
10 envelope or going beyond the design basis line and trying to
11 understand where we have to focus our attention if we were
12 going to try to put down a rule to address steam generator
13 problems.
14 One of the first things we did was design the INEL
15 that I think Dr. Bonaca has talked about where we tried to
16 scope where we thought problems may be.
17 One of the first things we did was analyze main
18 steam line breaks with different numbers of tube ruptures.
19 It was based on -- I will talk about that later -- modeling
20 assumptions, but the approach anyway was just see if there
21 is a cliff somewhere that was just outside of the design
22 basis envelope that we needed to really worry about in terms
23 of risk to the plant, of risk to the public.
24 In the end this analysis provided support for us
25 to concentrate on these -- I will call them severe accident

1 scenarios but the high and dry sort of things which we ended
2 up spending a lot of time and effort on in conjunction with
3 research and produced NUREG 1570.
4 Efforts continue in that area because of the
5 uncertainties that we were aware of from that 1570 work.
6 That was not the end of the process. It continues, but for
7 our purposes here I am just giving you a context for what
8 the INEL report represents.
9 It doesn't maybe go as far as these other efforts
10 that we call severe accidents. As I said, it summarizes the
11 analyses with multiple tube ruptures and combined main steam
12 line break events.
13 It used the RELAP model, RELAP5 model of Surry and
14 I think Steve mentioned that as part of this process we
15 found that we had these same questions about what is the
16 operator able to or not able to do. The licensee for Surry
17 was kind enough to send us their complete EOP package, which
18 the contractor was able to reference and use and they
19 answered questions for us when we got to the point that I
20 think Steve mentioned, that we were trying to use a
21 simulator to understand what operators could or couldn't do.
22 They answered questions about their own procedures.
23 In a way it is a very detailed look at one plant
24 and in a way it is unfortunate because we focused so much on
25 one plant at the exclusion of other designs but in the

1 course of the rulemaking we had to concentrate our efforts
2 somehow and that's what we did.
3 One issue that I was made aware of that I was
4 going to spend some time on but I might -- I will get your
5 sense, Dr. Powers, on whether we wish to spend time on this,
6 is the assumption that ECCS flow in the event was throttled.
7 It seems like there's other issues here, but with
8 the timing I might just jump to rather than discussing the
9 throttling issue.
10 CHAIRMAN POWERS: Well, it seems to me that the
11 critical issue is the kind of time that is available to
12 recognize and respond to the event --
13 MR. DONOGHUE: Right.
14 CHAIRMAN POWERS: -- and start throttling soon
15 enough. I presume that the operator -- I mean it is safe to
16 presume that the operator once he starts throttling will
17 throttle appropriately.
18 MR. DONOGHUE: Well, that's the question. I will
19 just touch on it very briefly unless there's questions that
20 come up.
21
22 Just to jump to the conclusions of the report, we arrived at
23 the point where we thought that, given, given the
24 procedures, that the RWST inventory at Surrey was sufficient
25 to handle the combined [inaudible] and multiple tube

1 ruptures, that dividing line at exact number of tubes is a
2 point of argument. But it seemed like it was, was not one
3 tube. It was not even maybe a handful of tubes. It was
4 probably something a little more than that.
5 Just briefly on the throttling assumptions,
6 there's different configurations at different plant, but for
7 Surrey, you can realign your high-pressure injection through
8 charging lines and have a throttling capability. The
9 emergency response guidelines with the CROPs allow -- they
10 have objectives of maintaining RWST inventory in the case if
11 you have decreasing steam generator pressure during a tube
12 rupture. And in order to do that, there are guidelines for
13 the reduction of injection flow.
14 Um -- I'll jump to the next-to-last bullet on the
15 slide. Is that -- the wording in this bullet maybe isn't
16 the best. But from the range of one to fifteen tubes,
17 different actions become more important. For the larger
18 breaks, the number larger number of tubes broke or failing,
19 it's less important that the operator depressurize because
20 it's happening already. It's happening by itself.
21 The other actions that are important are,
22 obviously, when and how to reduce injection flow and then
23 the big question -- the biggest question, I think -- is how
24 and when you get onto RHR. That's what's saving you.
25 There were people that were involved in this

1 analysis that still had questions when we got to the point
2 where we made some conclusions about this. However, as you
3 heard already, we didn't have information that gave us
4 credible means for getting to these multiple tube ruptures;
5 they're very high primary, secondary leakages during the
6 main steamline break. And we took the direction during this
7 rule-making trying to develop a technical basis for this of
8 going off in the other direction that I mentioned before,
9 the NUREG 1570 analysis.
10 Talking about the timing, I did bring a couple of
11 plots that came from the work that was done for the INEL
12 report. It was also -- the INEL work was also in -- the
13 NUREG number escapes me. It think it's 6365, steam
14 generator tube failures, I think is the title. Some of this
15 common, some of the same analyses ended up in both reports.
16 The more complete set of analyses were in the INEL report.
17 And it was kind of a, I guess, a scoping study, a draft sort
18 of document. It didn't make it into the NUREG stage; it was
19 a contractor report.
20 I'll just throw up here -- I might be going
21 backwards, but, all right, let me do this. If I put up the
22 one tube-rupture case, it's -- let me see the units. Okay.
23 With one tube rupture, the RWST inventory is somewhere
24 around that line. And if you extend, if you extend that
25 injection rate, that cumulative injection flow up to the

1 inventory, you can see there is several hours -- I think I
2 wrote down -- there's several hours that the operators have
3 to respond.
4 If you throttle the flow, which is what's done at
5 about, at about this point, and you throttle the flow, you
6 get a couple more, several more hours. So the one tube case
7 seems like there's plenty of time for operators to respond.
8 If I jump to the very limiting fifteen-tube case, you can
9 see there where flow was throttling, or without throttling
10 flow, you can see there's only roughly an hour before you're
11 done with the RWST.
12 And I'll point out that for Surrey, there's an
13 ability to cross-connect to the other RWSTs that's not
14 included in this analysis. This is just the one thing.
15 You can see when flow is throttled, that roughly
16 doubles the time that you have. And that is still of
17 concern. I wouldn't, I wouldn't feel confident saying to
18 the operators, given a fifteen-tube -- you know,
19 double-ended guillotine break of fifteen tubes would be able
20 to handle things, given that short period of time, even if
21 flow could be throttled.
22 I think I have -- here we go. I have a ten-tube
23 case, which is getting closer to that point that one might
24 think -- is that clear enough? Yeah -- that one might think
25 you could survive it. Again, just extrapolating these lines

1 up to about where the RWST flow, RWST inventory would be,
2 you can see you get quite a, quite a change in the time that
3 you have, from about -- oops, that's probably wrong, there
4 we go -- from maybe a couple of hours to five or six hours,
5 roughly, which highlights the importance of the operator
6 actions to reduce flow, but made it apparent to us that it
7 didn't see, even with this ten-tube failure case, that there
8 was going to be that -- we weren't on a hairy edge. If
9 there was just a few hours, we'd still be concerned, as I
10 mentioned on the fifteen-tube case.
11 When we were doing, when the INEL was doing this
12 work for us, these human error probability questions came
13 up. Steve alluded to some of the efforts that were pursued
14 to address them. I'm not gonna try to address them here.
15 I'm not even close to an expert; I'm just aware that that
16 work was done. However, when we got to a point where we
17 thought we understood it well enough to get some
18 risk-informed basis for what we needed to do, the work here
19 was considered sufficient.
20 DR. KRESS: What happens to the peak [inaudible]
21 temperature when you throttle it?
22 MR. DONOGHUE: Well. I think you just keep the
23 core covered.
24 DR. KRESS: -- keep the core covered --
25 MR. DONOGHUE: Yeah, I mean I have one plot here

1 where this is fifteen tubes and no operator action, no
2 throttling. You can see that -- where's that fifteen-tube
3 case with the throttling on it. You can see that the core
4 becomes uncovered and you start causing damage. But where
5 -- yeah, it's well after WST is emptied.
6 MR. WARD: Excuse me. My name is Len Ward.
7 There's no challenge to core uncovering.
8 MR. DONOGHUE: Yeah.
9 MR. WARD: There are two LIPSI pumps operating in
10 two [inaudible]. There's a tremendous amount of flow there.
11 Core uncovering is not a concern unless you have no
12 injection. And if you have no injection, you don't uncover
13 until seven hours. And that's because you basically have to
14 boil off all the fluid above the top of the core, from the
15 steam generator tube sheet all the way down into the vessel.
16 Roughly seventy percent of the fluid in the system is above
17 the top of the core. It takes a long time to boil it off.
18 If it was flowing out critically, if the break was
19 in the co-leg, it would lose it a lot faster. So the saving
20 grace, the good thing about these kinds of events are, the
21 break's very high in the system and you have to boil fluid
22 off. And that doesn't challenge injection systems like
23 critical flow does. So it gives you large amounts of time
24 before you would start to uncover.
25 MR. DONOGHUE: Thank you, Dr. Ward. I will just

1 --

2 MR. AOPEUFELD: One more comment. There's a
3 German study showing that only ten tubes, and they were
4 concerned about turning -- they can't throttle it, so you
5 have to turn pumps on and off. And they weren't designed
6 for it.

7 MR. DONOGHUE: Well, as I mentioned for Surrey,
8 there's an ability to realign the system to use the charging
9 lines to, which have the ability to throttle the flow.

10 In these cases, it was probably a simplifying
11 assumption that the throttling was done once and we stopped.
12 I'll just point out that for the fifteen-tube case, the RWST
13 runs out in a little bit more, around two hours, and that
14 the boiling is going on for another three to four or five
15 hours, before you end up having a core damage problem.

16 As far as -- the throttling assumption I think is
17 gonna be largely a plant -- it's gonna have to be, it's
18 gonna have to consider plant differences, design
19 differences. It's clear. Again, this scoping study, you
20 use one plant design to see if -- which we thought was
21 relatively representative of a large portion of the PWRs, to
22 get an idea of if there was a large risk significance to
23 these kinds of events.

24 I think this afternoon, if there's other questions
25 about the human error probability analysis that was done,

1 that's the appropriate time to talk about it. Are there any
2 other questions about that work? Yes?
3 DR. BONACA: The only reason -- okay, first of
4 all, I thank you for the presentation. That's the
5 information I wanted to have.
6 The reason why I asked directly before is that I
7 did not see it discussed into the DPR consideration in a
8 specific fashion, and so I was puzzled and I thought that
9 you would not be presented that information, which I believe
10 it's important to our judgments that we have to make here.
11 And again, I was intrigued by the fact that when we look at
12 the risk analysis, this information wasn't presented at all.
13 The DPL consideration. It is discussed under the accident
14 analysis portion, but it's not considered at all into that.
15 And that was my reason for asking for that.
16 MR. HOLAHAN: I would just add that a similar set
17 of analyses were done about a decade earlier, part of
18 resolving unresolved safety issues 83, 4 and 5, and had a
19 similar result for the one-, two- and ten-tube ruptures and
20 came up with similar conclusions as to the amount of time
21 available and the likelihood that operators could handle
22 those cases. And just to simplify again, in the context of
23 Dr. Hopenfeld's concerns, I think what we're both saying is,
24 is for a fairly small number of tube ruptures, the operators
25 have time and can probably handle these.

1 And in fact, I think both the staff and Dr.
2 Hopenfeld would say there is a point at which the sequences
3 do in fact go too fast and the situation is too complicated.
4 And whether that's ten tubes or twenty tubes, there is in
5 fact some point at which that occurs. So it seems to me
6 that the main issue is, what's the likelihood of having
7 multiple tube ruptures given the steamline break. And the
8 staff's conclusion is that's very unlikely and we'll discuss
9 it some more this afternoon, but that same view is not
10 shared by Dr. Hopenfeld.
11 DR. BALLENGER: But even if you have fifteen tubes
12 ruptured, what I just heard was that -- so you run out of
13 RWST water in two hours, and the operator's completely
14 flustered and can't deal with it. You've got six hours more
15 before the core is uncovered.
16 MR. HOLAHAN: No.
17 DR. BALLENGER: No?
18 MR. DONOGHUE: That's a total of about six hours.
19 You have maybe three or four.
20 DR. BALLENGER: So you've got four hours.
21 @@ DR. BALLENGER: Three or four hours.
22 @@ DR. BALLENGER: You've got three or four hours
23 more grace period, if you will.
24 MR. DONOGHUE: Yes.
25 CHAIRMAN POWERS: The problem is, once you concede

1 fifteen, you've got to concede twenty. Once you concede
2 twenty, you've got to concede twenty-five. I mean, one or
3 two is different from fifteen.
4 MR. HOLAHAN: And I think that as the number of
5 tubes would increase, in fact that amount of time available
6 would decrease, because it wouldn't just be boil-off. You
7 could actually have a system blowdown if the number of
8 failed tubes was large.
9 MR. DONOGHUE: If there's no further remarks about
10 that, I'll go to my last topic, which I won't even try to
11 say is going to be brief, even though I only have a couple
12 of slides.
13 We've touched on this I think earlier, the leakage
14 that could develop during a depressurization event. And
15 just point out that I have one other page that I want to
16 make sure you have. It's a list of events I'll get to in a
17 second.
18 When we talked about this in the DPOP
19 considerations document -- this I think is issue 2. And let
20 me see, break leakage. I think we've mentioned that there
21 have been depressurization events, we have not seen primary,
22 secondary leakage associated with those events. Those kind
23 of events are usually association with stuck-open relief
24 valves, loss of feedwater, or some combination of those,
25 those kind of failures. And when we look at the reports for

1 those, some of those events -- which I'll show you the list
2 in a second that I'm talking about -- we don't see a
3 discussion about primary and secondary leakage.
4 If there was primary and secondary leakage, there
5 are steps in the procedures that the operators use that take
6 that into account. If there's contamination going to the
7 secondary side, there's certain things they need to do.
8 They need to monitor for it, but there's also steps to take
9 to, to try to limit the contamination. But what's
10 important, I think, is that for the events that we're aware
11 of, that when plants returned to power, there was not tube
12 leakage that was reported to the NRC. We didn't see tube
13 failures manifested in leakage from these type of events.
14 DR. SIEBER: Could I ask a question.
15 MR. DONOGHUE: Yes.
16 DR. SIEBER: [inaudible] had a blowdown during a
17 [inaudible]. Was there an inspection or do you have any
18 information related to the condition of that steam generator
19 prior to its being put in service?
20 MR. STROSNIDER: Yeah, this is Jack Strosnider of
21 the Staff. You're referring to an event that we heard about
22 the day before yesterday, I guess. We've asked the staff to
23 go look at the docket and see if we have anything reported
24 to NRC. I can't tell you the answer at this point, but we
25 are pursuing that question.

1 MR. DONOGHUE: I would just add that I think in
2 the documents that you have, there's accounts of those
3 events, of that and I think and event at Robinson. And just
4 looking at those accounts, I didn't see any discussion about
5 the -- you know, going back and looking at the steam
6 generator. I did look at some other information I think
7 EPRI had on repair histories for tube. And I'm not sure if
8 Jack's staff has looked into that. I'm sure they are.
9 But, you know, it didn't seem like there were
10 tubes repaired at -- that's just speculation on my part.
11 That's just basically absent information; I think Jack's
12 staff will be able to answer that better. But for these
13 events, these are just examples of the type events that we
14 mentioned in the DPO considerations document, where in some
15 cases and in one case here, both steam generators lost
16 inventory.
17 The primary pressure changed, but the primary did
18 not depressurize during these blowdowns and there was
19 significant differential pressure across the tubes. I
20 wouldn't call these type of events are gonna produce any
21 kind of dynamic events that would be something, you know,
22 that could help address the new GSI. These are just purely
23 instances where you have a high differential pressure across
24 the tubes. But look at the LERS across these events, or in
25 the case of [inaudible], there's a detailed NUREG on that --

1 MR. HOLAHAN: My recollection is sitting up all
2 night in the operations center watching the Davis-Bessy
3 cooldown. And I think we asked some questions about whether
4 there was any leakage. And I think they did not have a
5 problem.
6 MR. DONOGHUE: Thank you. So there's another
7 piece of information that's helping. We didn't see tube
8 leakage after such events. And after we -- we don't know of
9 this being a problem for depressurization events. Which
10 leads to some assurance that if there's a high differential
11 pressure across the tubes, even after some period of
12 operation, that we're not going to see leakage develop.
13 HOPENFELD: [OFF MIKE]
14 MR. DONOGHUE: Say again?
15 HOPENFELD: [OFF MIKE]
16 MR. DONOGHUE: I'm not sure --
17 MR. STROSNIDER: That's correct. None of those,
18 none of those units particularly, you know, had the generic
19 letter number 505 alternate repair criteria in place.
20 HOPENFELD: [OFF MIKE]
21 MR. DONOGHUE: No, but the point is that the
22 plants operated -- these plants did have some tube repair,
23 although they weren't ultimate repair criteria. And it's
24 just showing that we don't have information to show us that
25 the tubes are going to leak excessively after a high, high

1 differential pressure is applied to the tubes.

2 CHAIRMAN POWERS: I feel, I feel absolutely

3 obligated to point out that after 24 launches of the

4 shuttle, we didn't have any evidence that we'd have a

5 Challenger.

6 MR. DONOGHUE: I understand --

7 CHAIRMAN POWERS: Small databases are useful for

8 contradicting hypotheses, not confirming them.

9 MR. DONOGHUE: I see. Well, we just wanted to

10 present the operational information that we knew about when

11 we wrote the DPO considerations document.

12 CHAIRMAN POWERS: And I think that's, that's what

13 the Committee asked for and it's useful.

14 MR. DONOGHUE: Unless there's other questions or

15 remarks, that's all I have for today.

16 CHAIRMAN POWERS: Are there other questions?

17 Speaker? Seeing none, I'd like to pose a question to Dr.

18 Shack. We let him get away way too easy on this, on his

19 presentation. So we'll take just a minute or two. Dr.

20 Shack, if I ask you a question, may I suggest you just sit

21 here in the designated Federal officials' seat.

22 [LAUGHTER]

23 CHAIRMAN POWERS: When you spoke, you spoke of

24 both circumferential and axial cracks and presented a

25 mind-numbing amount of data and analyses that suggest that

1 we really understand circumferential and axial cracks in a
2 fair amount of detail. But I'm reminded of the cracks that
3 people show us that show that they are not completely
4 circumferential or axial in all cases. And I'm wondering
5 how -- do we have guidelines to tell us how to apply all
6 that knowledge to more realistic cracks that have some
7 convolution of shape that might suggest that they have some
8 circumferential characteristics and some axial
9 characteristics.
10 DR. SHACK: One moment. I suspect this is more a
11 question of what the regulator is done when he's faced with
12 those questions. I think most of the time, unless one has
13 better information, one makes a rather conservative bounding
14 projection of the cracks, so that you're, you're almost
15 collapsing cracks that are separated by ligaments onto a
16 plane and using that kind of bounding analysis. There are
17 rules in the code, you know, if you could clearly
18 demonstrate the separation of these segments, but in many
19 cases, the resolution of the NDE isn't good enough, so you
20 would end up collapsing them.
21 We're looking in a research basis at what you do
22 when you have a combination of circumferential and axial
23 cracks together. We -- I think that one would again take
24 rather conservative estimates of how that would work, by
25 projecting everything onto a single plane.

1 SPEAKER: Cosine of the angle?

2 DR. CATTON: You don't get an oblique crack?

3 SHA: There's thousands of cracks out there, you
4 know. Never's a long time.

5 [LAUGHTER]

6 SHA: I would say that most of the time, you get
7 circumferential and axial cracks. I sort of explained it to
8 Dana, that one of the things you seldom see -- stress
9 corrosion cracks don't grow under pure sheer, typically.
10 We've tried to grow them under torsion, which is one way to
11 get a pure sheer state. You seem to need normal stresses,
12 and so they line up along principal stress axes, which in a
13 tube happen to be -- it's this way.

14 Now again, at a roll transition, the stress state
15 is always a little more complicated and things might not be
16 so simple. But the stress patterns there are so
17 complicated, my guess is you end up assuming that they're
18 projected into some 360-degree plane and you'll, you'll find
19 that you don't want to live with the results.

20 Again, if it was a small crack at an angle, as my
21 results show, you know, the 300 degrees, you're not gonna
22 quibble over one short, small crack. But if you have an
23 extensive amount of cracking -- but again, it's the
24 regulators who actually handle that problem.

25 MR. STROSNIDER: Yeah. This is Jack Strosnider.

1 And just to follow up on what Dr. Shack indicated,
2 typically, typically because of principal stresses in the
3 pressure, the large hoop stress and that, you're gonna see
4 axial cracks or circumferential cracks. That's -- in order
5 to get something that's, that's at some sort of angle, you
6 need something like the ODSCC under the tube support plates,
7 which is -- and even there, it, it lends itself to the
8 creation of something closer to intergranular attack, as we
9 said earlier. So you've got a network of cracks.
10 But as that crack develops -- and this is what's
11 applicable under generic letter 9505 -- is you leave, if
12 it's left in there long enough and as it develops, it will
13 develop a principally, an axially oriented, dominant crack.
14 You know, the one area where -- and unfortunately
15 I don't have any of the staff here who can go into a lot of
16 detail on this -- but my recollection is that down in the
17 crevice of the tube sheet, you know, some of these plants,
18 the tube are not full-depth expanded into that [inaudible]
19 tube sheet. It might be expanded three inches, and then
20 you've got this 20 or 21 inch crevice.
21 Down in that crevice region, where we have some
22 alternate repair criteria, all right, which are based on
23 depth into the, down into the tubesheets and the inability
24 to pull it out, friction loads and that sort of thing, my
25 recollection is that we have placed on some of those repair

1 criteria, some requirements that when they do the
2 inspection, they verify that the cracks do not have a
3 significant circumferential portion, because they do
4 sometimes grow. In that sort of environment, they may not
5 grow at perfectly along the length of the tube. So we did
6 establish some criteria there. That's my recollection. If
7 you want more specifics on that, I'll have to get it for
8 you. But it's something like that --
9 CHAIRMAN POWERS: Yes, I'd like to --
10 MR. STROSNIDER: -- it's that sort of unique sort
11 of situation down in that crevice where you might tend to
12 see something, you know, like you're --
13 CHAIRMAN POWERS: Yes, I'd like to know why you,
14 you asked for something particular about the circumferential
15 character to the cracks, because I got the distinct
16 impression from the explicit words that you could tolerate
17 circumferential cracks a lot better than you could axial
18 cracks.
19 MR. STROSNIDER: Well, I'm, I'm not sure if I
20 follow everything. Your question exactly is -- it was
21 discussed this morning, circumferential cracks are more
22 tolerable in the sense that you have, they have lower
23 stresses on them trying to pull them apart. In reality,
24 when you look at circumferential cracks, at least at the top
25 of the tubesheet, they tend to have a lot of ligaments in

1 them. That may not necessarily be true of some of the
2 primary water cracks that, that show up. But it's largely
3 because of the lower stresses that are on 'em.
4 With regard to these criteria down in the
5 tubesheet, as I said, we have to get some more specifics for
6 you. But sort of a general concept is that the ideas, you
7 want to make sure the thing doesn't pull out, all right?
8 And if you had the potential to grow a circumferential crack
9 completely around the tube, then, you know, that, that, you
10 know, too close to the top of the tubesheet, then you might
11 have some concern about whether you've got enough tube down
12 into the tubesheet to keep it in place.
13 All right. The other aspect of it is that the
14 axial cracks that are in there, you know, you have to look
15 at them from some sort of leakage point of view.
16 So I don't know if -- does that address your
17 question?
18 CHAIRMAN POWERS: Well, I mean, the question is
19 enormously naïve. You asked for some special NDA activities
20 in that region for circumferential cracks. I just wanted to
21 know why.
22 MR. STROSNIDER: Well, and I in general the
23 concern is that, as I indicated, you know, there's criteria
24 with how high are -- I don't know which way to describe it.
25 It's a better way to picture, you know. You don't want

1 degradation too close to the top of the tube sheet because
2 you want enough of the tube down into the tubesheet to
3 provide the restraint. And also, you don't want
4 circumferential cracking because, because it could impact,
5 you lose some of the frictional load and stuff.
6 CHAIRMAN POWERS: I guess I could understand the
7 frictional load. But my, what I understood you to say was
8 that you asked for more NDE in this region because the tubes
9 weren't full expanded and you had a long crevice region,
10 which isn't holding the tube in except for whatever friction
11 there is.
12 MR. STROSNIDER: And it's probably best if I get
13 one of the staff to come provide you some detail. But my
14 recollection is that what happens is that you can allow some
15 axial cracks, you know, getting closer to the top of the
16 tube sheet because they're not gonna impact at the pull-out.
17 All right, but if those axial cracks start showing some
18 circumferential orientation, all right, then you want to
19 limit that.
20 But let me make a note to get some more detail on
21 that for you.
22 CHAIRMAN POWERS: Yeah, I guess I'd like to
23 understand a little better because I came away distinctly
24 with the impression that circumferential cracks were rare,
25 even though you might have a limited capability to detect

1 them, that they were just much more tolerable.

2 DR. SHACK: No. I didn't say that, I don't think.

3 They're not rare.

4 CHAIRMAN POWERS: You didn't say that. I got that

5 from another speaker.

6 MR. STROSNIDER: I would point out --

7 CHAIRMAN POWERS: I could be equally wrong.

8 [LAUGHTER]

9 MR. STROSNIDER: I would point out one other

10 thing. And we didn't get into a large discussion about

11 leak-before-break in steam generator tubes, all right. And

12 in general, we do not credit leak-before-break in steam

13 generator tubes because, obviously, we've had failures where

14 leakage either wasn't there or wasn't adequate for the

15 operators to head off the failure. So we, in general, we

16 don't credit it. However, if you look at all those leakage

17 events that have occurred, in a large majority of the cases,

18 it in fact does come into play.

19 For circumferential cracks, particularly at the

20 top of the tube sheet, as we indicated this morning, the

21 failure loads or stresses required on those are 7,000 to

22 8,000 psi. I mean, they're, they're not a like a brand-new

23 tube, but they're still pretty high. However, they, they

24 may develop a leak, and that's an area where, you know, you

25 could argue that leak-before-break is the most likely

1 failure mode for those. All right, so -- they are somewhat
2 more tolerant from that regard.
3 MR. DONOGHUE: Nothing else for me.
4 CHAIRMAN POWERS: Okay. Thank you. I think we're
5 in a position now that we can take a recess for lunch until
6 1 o'clock.
7 [LUNCH RECESS 12:10 P.M. UNTIL 1:00 P.M.]
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1 AFTERNOON SESSION

2 [1:00 p.m.]

3 CHAIRMAN POWERS: So, I'll note for this portion
4 of the meeting Mr. Dudley is acting as our designated
5 federal official, guiding me with an iron hand, right?
6 I think at this point we are scheduled to turn to
7 the simple and easily tractable issue of severe accidents.
8 And Mr. Long has drawn the short straw here.
9 MR. LONG: That was a much shorter introduction
10 than I expected.
11 CHAIRMAN POWERS: Well, it didn't look like any of
12 your compatriots are here to help you either.
13 MR. LONG: Okay. We have a few of us on here.
14 I've got the first few on severe accidents. And we went
15 over a little bit of this earlier. Severe accidents are
16 pretty much the things that we were talking about earlier
17 that are starting from design basis accidents, but becoming
18 more complicated and perhaps going towards core damage.
19 Plus things that we've always analyzed as if they
20 were going toward core damage. So I've tried to put a list
21 of them up here.
22 CHAIRMAN POWERS: Let me ask you this question.
23 Would I be completely adrift if I argued that I can tell
24 operationally whether an accident is severe or an accident
25 is design basis by looking where the operators are working

1 from the emergency procedure guidelines or working from the
2 severe management action plan?
3 MR. LONG: Well, certainly they're going to start
4 with EOPs before they get to the severe accident management
5 plan, anyway. So it's more a matter of how far does the
6 thing progress. Things like steam generator tube rupture
7 that are supposed to be design basis accidents still have
8 the possibility of becoming complicated or adding errors
9 committed that will take them all the way to core damage.
10 So there's--
11 CHAIRMAN POWERS: But I can tell the difference
12 between a design basis steam generator tube rupture accident
13 and a severe accident involving a steam generator tube
14 rupture. If I wait long enough by seeing if the guy stays
15 and his EPGs or goes to Sam?
16 MR. HOLAHAN: That the procedures are written in
17 such a way that the event, you know, drives you through the
18 process.
19 CHAIRMAN POWERS: Yes, I understand that.
20 MR. LONG: I guess what I'd say to try to answer
21 your question is the design basis accident is one that
22 pretty much doesn't go beyond what chapter 15 analyzed.
23 MR. KRESS: I think that's a best way to do it.
24 MR. LONG: And a severe accident is one that has
25 gone somewhat past what chapter 15 analyzed that you now

1 have core damage that's significant enough to make
2 substantial radiological release from the core. And there's
3 probably a substantial gap in between those two, where the
4 accident is probably beyond design basis, but not yet
5 severe.
6 At any rate, we try to break them down into
7 sequences that start along those paths, and just to sort of
8 get the group of things on the table that we're going to
9 talk about. There's the spontaneous tube rupture that start
10 as a design basis accident at least, and perhaps gets as far
11 as core damage.
12 There are sequences initiated by things that are
13 within the design basis, like secondary depressurizations
14 that increase tube pressure differentials and may lead to
15 things beyond design basis, like rupture of tubes or leakage
16 beyond the design basis values, that also have a potential
17 for getting to core damage.
18 There are sequences like ATWES that are not really
19 design basis, also increase tube differential pressure by
20 increasing primary system pressure rather than decreasing
21 secondary side and we do have in PRAs going to core damage.
22 And then there are the things that don't really
23 involved tube rupture to get you to core damage, but -- such
24 as station blackout or other things that usually loss of
25 second cooling, loss of primary inventory, that may, in the

1 process of getting to core damage, also affect the steam
2 generator tubes and perhaps convert some of these things
3 from accidents where the core damage is contained within the
4 containment structure to accidents where the radioactive
5 materials bypass the containment structure.
6 So all of these would potentially increase risk to
7 the public in terms of radiation exposure and the health
8 consequences that are created by that.
9 So that's the--
10 CHAIRMAN POWERS: You said increase, do you really
11 mean contribute to?
12 MR. LONG: They increase the probability of is the
13 best way of saying it.
14 MR. KRESS: They contribute to, Dana, but I think
15 the increase would be comparing to what you would have if
16 you didn't have the alternate repair criteria.
17 MR. LONG: I'm not sure what his baseline was. In
18 other words, there's the--
19 CHAIRMAN POWERS: I wasn't either.
20 MR. LONG: There's the baseline LERF, which is
21 just taken as what people are calculating in their PRA, and
22 that's not necessarily a complete representation of LERF.
23 We think there's some pieces missing.
24 CHAIRMAN POWERS: Gee, I can't imagine what they'd
25 be.

1 MR. LONG: Well, we'll talk about them. And then
2 there's the question of if you have a licensing amendment
3 request, would that change you from whatever the baseline
4 was. Maybe that baseline had to be augmented to begin with
5 to something that's substantially higher. Then we'll get to
6 the last topic of the day, which is the risk informed
7 decision process.
8 Anyway, to just launch into the different
9 sequences. The spontaneous tube rupture sequence is one
10 that's been in PRA's basically since the -- I guess it was
11 Point Beach Plant, pointed out that they needed to be in
12 PRAs. I don't believe it was in WASH-1400. And I wanted to
13 start with this one because it's the one that's been
14 analyzed most so far, and we can learn some things from it.
15 It's been treated in all the IPEs. Most of them
16 have a number that's very close to one times ten to the
17 minus two as the initiating event, frequency per year.
18 However, they have a wide range of results in the core
19 damage frequency in a per year basis that results from that.
20 We don't fully understand the reasons for the wide variety
21 in results. But we look into it -- we see that for the
22 results that come up on the high side, they seem to be
23 dominated by human error probabilities. And for the results
24 that come up on the low side, there seem to be more hardware
25 failures and less human failure represented in the dominant

1 cut sets.

2 MR. CATTON: Are the ones that are on the high

3 side from plants where they've had an event?

4 MR. LONG: Not necessarily.

5 MR. CATTON: Not necessarily?

6 MR. LONG: So it looks like the human error

7 probability modeling process is really what creates a lot of

8 the difference in the results we see in the IPEs. And it's

9 not just a matter of what number they put on the human error

10 probability that appears in the model. It's also where they

11 put the human error probabilities in the model--which ones

12 are represented, which ones may not be represented.

13 At any rate, as modeled now, especially if it's

14 the batch that have the higher values for a steam generator

15 tube rupture core damage contribution, that's usually one of

16 the dominant contributors to the total results in public

17 health consequences, not the core damage, but to things like

18 LERF-50 go to LERF, but more to population dose, cancer

19 effects, other effects from that population dose.

20 So that makes it pretty important to understand

21 how that would be affected by licensing actions.

22 Moving on to the next one.

23 MR. HIGGINS: Phil, so does the licensing action

24 for 9505 change the -- either accident sequence frequency

25 core damage frequency or LERF related to this type of severe

1 accident?

2 MR. LONG: We don't expect anything we're doing to

3 increase the probability of spontaneous tube rupture --

4 anything we're approving. We're trying to keep things that

5 we approve to where they would still meet the three delta p

6 criterion, and you know, the intent is to not increase this

7 probability.

8 Sort of going in the order that the questions were

9 asked, but not quite. One of the questions was about

10 station blackout accidents, and really what we're talking

11 about is a core damage frequency, the component of core

12 damage frequency that has high RCS pressure and a dry

13 secondary side. In other words, the high dry frequency as

14 we call it. And when we say high, we don't mean necessarily

15 sitting on the safety valve set point, but down to where you

16 still haven't really injected your accumulators.

17 There are a lot of ways of getting there. It's

18 usually mostly station blackout, but some plants are

19 actually dominated by loss of DC bus or buses. Small LOCAs

20 with loss of secondary cooling. Pretty much anything that

21 allows the core to become uncovered and damaged and has the

22 secondary side dry has the potential for producing a

23 transport of heat to the tubes without the secondary fluid

24 to cool the tubes.

25 The concerns then for steam generator tube rupture

1 affecting the progress of this event are the -- if a loss of
2 secondary integrity occurs to the point that the secondary
3 depressurizes as well as dries out, you have a delta p just
4 like you would for the main steam line break, you can -- if
5 you can rupture or cause gross leakage in tubes for the main
6 steam line break event, you could also for some of these
7 sequences.
8 The other aspect is if the tubes are strong enough
9 to withstand the delta p at normal operating temperatures,
10 if they become hotter, they may still fail as the, you know,
11 material weakens at the higher temperatures.
12 So these perturbations by tube degradation are
13 usually not included in the IPEs. The -- some of the IPEs
14 have picked up the one point four percent, I think it is,
15 that was in the NUREG 1150, 4550 plant risk models as an
16 expert elicitation process for what fraction of the time
17 they thought there would probably be a pre-existing tube
18 flaw that would be sufficient to cause the tubes to fail
19 first under these conditions. But most plants haven't
20 picked up a -- anything beyond just that one number that
21 came out of expert elicitation and looked at the sensitivity
22 of that number to tube integrity measures that are plant
23 specific.
24 When we did NUREG 1150, we tried to go into a
25 couple of PRAs, primarily the Surrey NUREG 1150 PRA, and

1 search for high dry sequences and try to get some estimate
2 of the timing to see if the RCS would be pressurized before
3 the steam generator or the other way around, and asked
4 ourselves if we'd have a -- just a pressure-induced failure.
5 I mean, a lot of work was done to see if the failures could
6 be thermally induced.
7 The factors that we had to consider for RCS
8 pressure involved the reactor coolant pump seals and the
9 burn off rate they would have. At least early on, there
10 were a lot of large seal leak scenarios that were
11 considered. Also, if the tubes are leaking substantially,
12 that's another issue with -- that I'll get into a little
13 deeper later, but it has to do with RCS pressure at least.
14 Pressurizer valves may also stick partially open. Avery did
15 some studies to determine if you continued to pass either
16 water or hot -- they didn't look at very hot steam -- but
17 repetitive openings of valves has a tendency to cause the
18 valves to not fully close, and we've run some cases where we
19 stuck pressurizer valves partially open.
20 These all seem to have effects that are reasonably
21 important to consider, but they're complicated. So we'll
22 get into a little more of that later.
23 Other things to consider are what's happening on
24 the secondary side, the main steam line safety valves may
25 stick. That's been in a lot of the PRAs for a long time.

1 There are other valves, like the turbine driven aux feed
2 water supply -- steam supply line. If you run out of
3 batteries, you may need to -- and can't control the
4 governor, you may need to think about closing that line.
5 The MSIVs may leak. We've had events where plants have been
6 able to, you know, lose a lot of fluid through an MSIV, and
7 not really notice it during their normal operation for start
8 up. The time they seem to discover this is when they have
9 to do a secondary site hydro, and they realize that they
10 can't pressurize the secondary site for the hydro, and then
11 they go find the leak.
12 The thermodynamics of the reactor coolant system
13 heat up control how the heat can be transported from the
14 oxidizing core, really, is the point at which this is
15 important, after the core has been uncovered and heated up
16 on decay heat, and it starts to get a chemical addition to
17 the heat up rate due to the oxidation of the clad is about
18 when these things really start to become important for over
19 temperature in the tubes.
20 And the thermal hydraulics of the process can be
21 important here if the -- if there's full loop convective
22 circulation through the tubes, especially if the tubes are
23 depressurized on the secondary side, it looks like even new
24 tubes, pristine tubes, will not be able to withstand the
25 heat up without being the first component to fail. They're

1 thin, and the heat up process is fairly rapid.

2 However, there are places where this full loop

3 circulation can be blocked. There can be water in the

4 suction to the reactor coolant pump, and they call it the

5 loop seal. There can also be water left below the core

6 that's blocking the down comer such that you don't really

7 have a path below the down comer and up through the core.

8 If you get into scenarios where you are

9 depressurizing -- excuse me, drying out the core without

10 depressurizing, and then you put a fairly small leak in the

11 system, you have a potential for boiling away loop seals,

12 getting flows re-establishing loop seals. And this has

13 turned out to be quite complicated. So we've had -- you

14 asked some questions about stylized sequences, and in NUREG

15 1150 time period, we were looking at either the reactor

16 coolant system stays at the safety valve or pressurizer for

17 set points, or there were large leaks in the RCS, in the

18 reactor coolant pump seals, and the whole thing

19 depressurizes; the accumulators eject.

20 We've more recently started to look at situations

21 where leakage is in one or another part of the RCS -- take

22 the pressure down low enough to stop cycling the pores, but

23 not necessarily to dump the accumulators or at least not low

24 enough to really remove the pressure from the tubes

25 completely. And this prolongs the accident. It gets into

1 much more complicated phenomena.

2 There may be different delta p's among the

3 generators, and within the generators the temperature may

4 vary. And I have a slide I just want to throw up here real

5 quick. But this is from the 1/7th scale test. I don't know

6 if this is a slide you'll be able to read. At any rate, the

7 -- there's 216 tubes, and the sort have been partitioned

8 along this dotted line to be the tubes that were thought to

9 carry flow upward and -- well, out of the inlet plenum or

10 the outlet plenum, and then the rest of the tubes -- the

11 outlet plenum being over here -- and then the rest of these

12 tubes were carrying flow from here back around into this

13 side. And the temperature distribution on here, although

14 the peak is right around in here, and you can it's, in this

15 case, 178 roughly degrees. Over here, it's maybe 143

16 degrees. Over here, it's a 145 degrees. So there's quite a

17 variation in this batch of tubes that's modeled as being the

18 hot bundle.

19 And when we get into trying to act -- ask

20 ourselves how big does the crack have to be to cause failure

21 if experiencing temperatures in the hot bundle. Right now,

22 we don't have a good way of describing the distribution of

23 temperature within that hot bundle. RELAP gives us one

24 number for the entire hot bundle. So that's been a problem

25 for us as well.

1 So all of this has gone into our thought process
2 about how to deal with the high dry frequency. At this
3 point, we're going to have discussions later on how to model
4 that. I don't want to go into it much more deeply yet.
5 We'll get back to how we used it later. Are there any
6 questions on the high dry sequences as to what they cover or
7 what we're trying to include?
8 MR. HIGGINS: Are you going to get to results in
9 terms of numbers, increase in delta LERF, and that sort of
10 thing for 9505?
11 MR. LONG: 95-05 we wouldn't expect to see any
12 delta LERF. That was part of the premise, that we weren't
13 going to be increasing core damage frequency or LERF.
14 MR. HIGGINS: But wouldn't the times at which you
15 get two failures change with the 95-05 criteria, so why
16 wouldn't you see a difference?
17 MR. LONG: Okay. In the -- 95-05 allows
18 degradation to occur where it's confined by tube support
19 lights. And the thinking in the time was the blow down that
20 you would get from the secondary side, from the things I was
21 discussing -- are stuck valves, other things that we've seen
22 blow downs before. We don't expect that to really move the
23 tube support plates off of those damaged portions of the
24 tubes. There is one issue that I don't think anybody has
25 really--

1 MR. HIGGINS: But I didn't think you were taking
2 credit for the tube support plate restricting and preventing
3 leakage.
4 MR. LONG: Those are steam line break cases. In
5 the design basis analysis for steam line breaks, they are
6 not taking credit for it. In a risk assessment, we would be
7 taking credit for it, unless we had a reason to believe it
8 wouldn't be there.
9 MR. CATTON: There's another factor, too. You
10 know, even if -- although we may disagree on the mixing and
11 so forth, the cracks that are going to be in the vicinity of
12 the support plate, you got a huge heat sink. So that's
13 really not where you're going to heat up the tubes.
14 MR. LONG: On the support plate, I'm not sure how
15 big the heat sink turns out to be. But--
16 MR. CATTON: Well, but it is a heat sink.
17 MR. LONG: To some degree, yes.
18 MR. CATTON: So if you're going to heat anything
19 up, you're going to heat the freestanding parts of the tubes
20 more than you're going to heat the -- where there's a big
21 solid chunk of metal.
22 MR. LONG: You're talking about the support plate,
23 and not the sheet. The sheet clearly is a big solid chunk
24 of metal.
25 MR. CATTON: About two feet thick. Even when you

1 have three-quarter inch thick, that's steel, and it's a heat
2 sink.
3 MR. LONG: If it's there, it will prevent.--
4 MR. CATTON: It will prevent it from heating up as
5 fast as it goes somewhere else.
6 MR. LONG: The one thing to think about, though,
7 is if you have a bundle of tubes that are hot, and these are
8 hotter than those, what does that do in differential
9 expansion? We think it will probably kind of bowed the
10 tubes, but we haven't really looked at if that effect on the
11 tube support plates.
12 MR. CATTON: Are those the thermal couples that
13 were in the inlet of the tubes, or are they just below the--
14 MR. LONG: I believe, if you look up here, these
15 are -- the dots are one inch from the tube sheet bottom.
16 The closed triangles are three inches from the tube sheet
17 bottom. I believe that's in the tubes. And then the open
18 pointed down triangles are point seven five inch below the
19 tube sheet. So there's a variety of them in here.
20 MR. CATTON: Surely, you'll explain all this
21 later.
22 MR. HIGGINS: So, Steve, in this last group you've
23 included both ones that would induce tube rupture by both
24 thermal high temperatures on the primary side, due to the
25 core damage and ones that would be induced due to the high

1 delta p?

2 MR. LONG: Right.

3 MR. HIGGINS: And you're saying neither of those

4 would result in increased numbers for the 95-05?

5 MR. LONG: When we did 1570, we weren't really

6 thinking about the 95-05 degradation. We were thinking

7 about free spanning cracks that were in the sludge pile or

8 other areas that were not confined. And the -- at the time

9 that we did NUREG 1570, the industry had asked for

10 essentially a five percent conditional failure probability

11 in the free span for main steam line break, because they had

12 looked at NUREG 0844, and NUREG 0844 had concluded that

13 basically we wouldn't back fit them if we had five percent

14 conditional failure probability of tubes, given steam line

15 break. So the industry was sort of turning this -- well,

16 it's not bad enough to back fit them into a performance

17 criterion if they could. We were trying, in NUREG 1570, to

18 add to our knowledge base what would happen if we had that

19 level of degradation. So the numbers in 1570 are -- we

20 tried to peg to something that would give a five percent

21 conditional failure probability for steam line break, and

22 then ask ourselves for that, what do we expect in severe

23 accident conditions.

24 So we weren't trying to develop something we would

25 accept. We were trying to explore what would be the case if

1 this occurred.

2 MR. HIGGINS: Yeah, I guess what I'm trying to
3 explore and see -- and I thought maybe we would get to it as
4 we went through this was that whether or not for the various
5 different types of core damage sequences that are important
6 to steam generator tube rupture in 95-05, what do the
7 results look like in terms of increases in core damage
8 frequency or increase in LERF, and is it reasonable in
9 severe accident space? Is what you've done reasonable in
10 severe accident space? But it sounds like what you're
11 saying is you don't have all those numbers?

12 MR. LONG: What I'm saying is when we did 95-05,
13 actually when we did the interim plugging criteria, which
14 became 95-05, the intent was not to increase core damage
15 frequency or LERF at all. And the basis for that was the
16 belief that we had confinement of the damaged area, the
17 degraded area, by the tube support plates. There was a
18 concern for what was considered to be a very hypothetical
19 kind of main stream line break that you might move the
20 support plate relative to that degradation. We didn't know
21 how to calculate the -- actually the clamping effect of the
22 tubes on the support plates, given that the -- you know,
23 that the -- or I should say it the other way around. But
24 the support plates are denning the tubes. That's why we
25 have the degradation, and there is quite a force per tube,

1 which they have to overcome to pull them.

2 So there was a feeling that realistically the

3 support plates were pretty well held in place by the tubes.

4 From the design basis, they were having trouble

5 quantitatively crediting it, so they did not. And they went

6 to the -- what we were considering to be a hypothetical leak

7 rate and a hypothetical conditional burst probability. Now

8 there is some stuff in 1477--

9 MR. HIGGINS: Are you going to represent anything

10 to -- or do we have anything already that provides some

11 justification for that?

12 MR. LONG: Provides justification for the tube

13 support plate not moving?

14 MR. HIGGINS: For clamping the leakage, any

15 leakage that might come from failures or to prevent failures

16 of those defects?

17 MR. LONG: Where's Joe?

18 MR. DONOGHUE: I'm sorry. Which one?

19 MR. LONG: The question is, are we going to

20 present anything about reason to believe that the tube

21 support plates really are held in place as far as doing a

22 risk assessment is concerned?

23 MR. DONOGHUE: I don't have any material on that

24 one.

25 MR. LONG: Yeah, I don't -- I guess that's

1 something that we could take as an action item to try to put
2 together.
3 MR. HIGGINS: But you're saying that's the basis
4 for your concluding that none of these core damage sequences
5 show any increased in LERF?
6 MR. LONG: That was the basis for granting the --
7 you know, the 95-05 plugging criteria. Without having done
8 a detailed study of the leak rate in a realistic framework.
9 In other words, when it came to what I would put in a risk
10 assessment, the risk assessment was not done until after
11 those were evaluated. We had not done 1570 when the interim
12 plugging criteria was out. We had discussed it. There was
13 a qualitative feeling that for a realistic blow down, the
14 tube support plates would be in place, and that's really
15 what we were basing it on. The risk -- that -- the --
16 that's what we were basing the lack of a formal risk
17 calculation on at that time.
18 MR. BONACA: Let me just ask a question. I know I
19 understand what happened at the time before 1570 and 1477,
20 but my main concern here is -- the thrust of my question was
21 because the DPO, the DPO claims that a certain scenario
22 which you define severe, it's possible. It is likely, and
23 they assign a high risk frequency to it. And that's the
24 DPO. When I read the DPO consideration, I found that the
25 very scenario that they are discussing there is not being

1 quantified or addressed in the DPO consideration. The DPO
2 consideration only addresses the possibility of leakage
3 considering 1477 up to about a thousand GPM, with some
4 assignment of risk to that -- ten to the minus six. And
5 then addresses the consequential failures of tubes resulting
6 from station blackout, and then it says any more, you know,
7 tube failures from main steam line break is not considered
8 likely or possible. Therefore, there is not quantification
9 or that. So it's very hard to evaluate the DPO
10 consideration because there is a lack of information
11 regarding how -- because it's the only denial that the event
12 can happen. And just the point I want to make is that --
13 that's why, by the way, to explain it, I jumped to the INEL
14 report, because the INEL report does also some human
15 reliability analysis. Now, the reason for digging into it
16 for me was to understand how reliable the reliability
17 analysis was, and I'm beginning to get a sense of it now.
18 MR. LONG: Okay, let me try to tease apart two
19 things.
20 MR. BONACA: Yes.
21 MR. LONG: Jim has been asking about 95-05, and
22 you've been asking about the DPO. And they're not
23 identical. What we were trying to do were the NUREG 1570
24 work was think about things that we thought might be able to
25 fail in the free span. In other words, another part of the

1 DPO was that there are so many cracks out there we can't
2 detect -- that might be in the free span, not just things
3 that are detected but left in service under the support
4 plates -- that, in fact, you might get a huge leak rate, if
5 not actually ruptures, in the free span. So when I was
6 answering Jim Higgins' question about 95-05, I wasn't trying
7 to say we didn't consider other reasons that there might be
8 failures of tubes. The -- but -- now to go to the other
9 reasons.
10 I mentioned earlier that we received from Dominion
11 Engineering some estimates of populations of flaws in steam
12 generators, in various types of degradations. And the ones
13 we concentrated on for NUREG 1570 were the ones that were in
14 the free span, not the ones that were under the support
15 plates. And we tried to pick a distribution of those which
16 turned out to be either average distribution that looked
17 like it would give a conditional failure probability under
18 main steam line break of five percent. And that was
19 basically one tube out of five percent, one or more. But
20 the way it works out is essentially one.
21 With 1570, there was some other work done in
22 parallel with that to ask, and I'll try to get to that at
23 least the beginning of that in a minute here, to ask what
24 are the thermohydraulics for a larger number of tubes. But
25 when it came to the risk calculation, I need the initiating

1 event frequency, which would be something like the
2 non-benign -- non -- what was the word you were using
3 earlier this morning? It was the gentle main steam line
4 break or something?
5 CHAIRMAN POWERS: No. It was Ivan's mild steam
6 line break.
7 MR. LONG: Mild main stream line break. So the
8 wild and wooly main steam line break frequency times some
9 conditional probability given that wild and wooly break that
10 you would rupture a certain number of tubes. And it was
11 that second parameter, which was essentially treated as zero
12 for a large number of tubes in the risk assessment, because
13 if we didn't have any knowledge of a way to get a larger
14 number of tubes ruptured than a few.
15 MR. CATTON: I didn't know you -- give it a
16 number.
17 MR. LONG: You said give it a number?
18 MR. CATTON: Well, now you have a way to get that
19 large number of tubes.
20 MR. LONG: Well, we have a hypothesis.
21 MR. CATTON: I don't know if it's real, but--
22 MR. LONG: We have a hypothesis, but the trouble
23 is if you put in a conditional probability of zero, you'll
24 end up about where we did in 1570 for the other types of
25 degradation. And if you put in a number - a conditional

1 probability of one, you'll end up where they prioritization
2 for the GS-123.
3 MR. CATTON: EDA. I thought we were doing zero
4 one.
5 MR. LONG: Which is -- well, what gets you up to
6 something like, you know, 3.4 times ten to the minus four
7 was it? And that becomes a matter of opinion, where you are
8 in that range if you believe that you can damage a very
9 large number of tubes, without some way of quantifying the
10 probability of how many tubes you would damage, you can't
11 see anything more than you're in that range. But first,
12 you'd like to know that it's really possible to, with, I
13 guess fatigue, grow these cracks and damage the tubes.
14 MR. SIEBER: But none of that has anything to do
15 with 95-05, right? Nothing in the free span?
16 MR. LONG: Assuming the support plates stay in
17 place, then that shouldn't--
18 MR. SIEBER: Right.
19 MR. LONG: 95-05 should not be affected by that
20 phenomenon.
21 MR. BONACA: But, you know, typically, I mean,
22 when you don't know, it's not really zero or certainty. You
23 tend to do sensitivity analysis to make -- get an
24 understanding of what it could be. Again, I thought I had
25 read them in the INEL report. They're right there. And so

1 I was trying to myself personally calculate what they could
2 be -- to see what -- how reasonable this could be. And a
3 big dependency actually was operator action.
4 MR. LONG: Right.
5 MR. BONACA: Because ultimately you come back with
6 pretty low with pretty low numbers anyway, if you believe
7 that the operator can handle it, even if you assume
8 conditional probability of tube failure to be one. And so,
9 I mean, I don't think it was that speculative. I just -- I
10 wanted to explain how -- I mean, I was looking for an
11 evaluation that would answer the DPO, and I just couldn't
12 see -- there was a window there that I -- didn't seem to be
13 covered.
14 MR. LONG: Okay. Well, I don't think it is
15 covered if you say that there may be a very high conditional
16 probability of failing 10, 15, 20 tubes, because the human
17 error probability in that case pretty much becomes one. So
18 you really don't have the ability to--
19 MR. BONACA: No, no, no. We just heard this
20 morning that there is significant probability of success
21 after about ten tubes.
22 MR. LONG: Well, that's what I said. If you go
23 10, 15, 20 tubes, if you believe that that's possible, with
24 a significant probability, conditional probability, you'd
25 have to get that conditional probability down to where it

1 and the initiating frequency for the wild and wooly steam
2 line break, just those two together, were low enough to not
3 matter to your conclusions.
4 MR. BONACA: I agree in the range. Yes, I agree
5 with you. If you go above the 10, 15, you really -- it
6 depends very much on the conditional probability. I agree.
7 MR. LONG: So the conditional probability of
8 rupturing, let's say, between 10 and 20 tubes, if it's below
9 ten to the minus four, you're fine. You don't need the
10 humans to do anything to keep the net contribution of risk
11 low.
12 We're sort of getting over into my next slides.
13 Trying to put the question you asked about other things that
14 might be initiated by something other than tube rupture, I
15 believe you mean, and lead to tube rupture. There are the
16 secondary depressurizations we've been talking about.
17 There's also the primary overpressurization events, and just
18 -- I think maybe I should try to go through these slides
19 fairly quickly, because we've kind of talked about them.
20 The potential initiators for secondary
21 depressurizations are things like stuck main steam safety
22 valves. We've had a steam dump control problem in the one
23 plant that doesn't have MSIVs. That was a coning that
24 resulted in blowing down the generators. Spontaneous breaks
25 in the main steam line safety valve headers. We've seen

1 those occur during hot functional testing, pretty
2 operational. It turned out to be a design problem that they
3 really weren't designed for reactive loads. So that sort of
4 brings up the question if they're not designed with reactive
5 loads with steam, but that's been fixed, now if we talk
6 about overfill events, and you start putting the weight of
7 water and the reactive loads of discharging saturated
8 fluids, now do you have a problem with the breaking the
9 header, as opposed to just sticking a valve. We have right
10 now a licensing action from Catawba requesting that they not
11 have to deal with certain single failures on overfill, and
12 we've asked them, are you confident that if you overfill
13 and, you know, discharge saturated water that you are
14 structurally capable of withstanding the loads. And they
15 don't know. So they have a conditional failure probability
16 of point one for those events, and they're -- it's a
17 risked-informed application. So we're pursuing that. So
18 there's a variety of ways you could get into having - not
19 only an open secondary, but maybe an open secondary you
20 can't recover.
21 CHAIRMAN POWERS: They put point one on the
22 conditional probability of an overfill event?
23 MR. LONG: Sticking a safety. In other words,
24 they were calculating conditional probability of overfill,
25 and they were looking for what would take them to core

1 damage. And their conditional probability of sticking a
2 safety valve, given that they're discharging saturated fluid
3 through it was point one. And we were, and, of course, they
4 have a potential for somehow recovering it if it sticks. So
5 there's questions of realism, of, you know, maybe you break
6 the header and you wouldn't have a chance to recover, and
7 there's also the question, can they really gag a safety
8 valve while something's passing through it.
9 The conditional probability of the tube rupture
10 depends on the probability that there's a susceptible flaw
11 in the free span and the generator that's affected by the
12 blow down. And that's something that's part of the DPO.
13 There's the question of how well can you detect the flaws
14 there. We've heard some of the POD discussions, but most of
15 the detection is done with a bobbin coil.
16 CHAIRMAN POWERS: Maybe you've just been simple
17 here, but it be in the free span or in the U.
18 MR. LONG: That's true. And in the U, I don't
19 think -- Jack, in the U they need to test with something
20 other than a bobbin coil -- to be--
21 MR. SIEBER: RPC.
22 MR. LONG: So it has to be an RPC up there. The
23 -- I'm losing my train of thought. I guess Calvert Cliffs
24 had a problem with detecting things in the free span and
25 actually did a rotating pancake coil, actually a plus point

1 inspection of a large quantity of the free span, and they
2 found a lot of things, they didn't find with the bobbin.
3 They then had to go back and find -- do the same thing again
4 after a short period to show that those things had been
5 there for quite a while, as opposed to they were suddenly
6 growing in rapidly after initiation. But it looks as though
7 the bobbin coil has the kind of PODs that we were describing
8 to you yesterday. So there is a potential for missing some
9 things. It's just a matter for probability.
10 MR. HIGGINS: And the reason here, again, that you
11 limit it to the free span is because you're assuming that
12 the TSP will restrain any cracks that are there?
13 MR. LONG: For this case, we were assuming that
14 the type of degradation allowed by 95-05 would not
15 participate in the ruptures, yeah.
16 Human error probabilities are real important here.
17 We've already discussed that; that depending on how much you
18 rupture it, it may be possible or not possible for the
19 humans to really respond in a timely way. But even when you
20 have something that's well within their capabilities, just
21 like with the spontaneous rupture initiating the event,
22 there is opportunity for errors of omission or commission to
23 take you to core damage if you've ruptured the tube. And
24 the difficulty here is you really have to get to cold
25 shutdown to terminate this event. Whereas, if the rupture

1 is spontaneous, you have the option -- the opportunity at
2 least of getting down to below the main steam safety valve
3 set points, and if they've closed, you basically have
4 terminated your LOCA. So this -- it's a little more
5 difficult.
6 We were assuming that mitigation of about ten full
7 ruptures is possible, but we didn't try to -- we didn't have
8 a frequency for that many ruptures, and we didn't really
9 push hard on the human error probability there. These
10 numbers are the things you've already dug out of the INEL
11 report. But they didn't -- at ten tubes, they really didn't
12 bear in the risk assessment results at all.
13 And as we've discussed before, we're kind of
14 sensitive to the idea that we're looking for mechanisms that
15 could fail a lot of tubes, and if you bring me one, I'll
16 certainly put it in the risk assessment. But at this point,
17 it's hard to put something in that you can't really credit
18 physically.
19 CHAIRMAN POWERS: How about blow down forces?
20 MR. LONG: Well, that's why I'm saying. If that
21 turns out to be something that looks like it has the
22 potential, we'll definitely put it in the risk assessment.
23 To try to be complete, let's talk a little about
24 actions initiated by overpressure events. The initiator is
25 really ATLAS.

1 MR. CATTON: Before you leave?
2 MR. LONG: Sure.
3 MR. CATTON: For tubes without flaws, what
4 probability of failure do you assume to the overheating by
5 the hot gases?
6 MR. LONG: Right now, the way the calculations
7 have been done since NUREG 1150, they're calculated on the
8 temperature of the surge line and the creep carrier damage
9 accumulation in the surge line.
10 MR. CATTON: So you're assuming.
11 MR. LONG: Versus the one number for the inlet
12 temperature of the hot tube bundle from RELAP. If you do
13 that, you get about 20 minutes, if I believe, time period
14 between--
15 MR. CATTON: Well, that's not the question.
16 MR. LONG: So I would get zero on that basis.
17 MR. CATTON: Zero?
18 MR. LONG: Zero. Now, when I put flaw in--
19 MR. CATTON: Well, that's nonsense.
20 MR. HOLAHAN: Be clear. You're not assuming zero.
21 You're doing the calculation and in the model, you're
22 calculating the clean tube temperature and its likelihood of
23 failure. And there is a model for likelihood of failure of
24 tubes with no cracks, which I think is what the question
25 was.

1 MR. CATTON: That was the question and the answer
2 is that the probability of failure of the intact, undamaged
3 tube is zero.
4 MR. HOLAHAN: No.
5 MR. LONG: The way NUREG 1150, 4550 did it--
6 MR. CATTON: I'm not going to -- well, what did
7 you do in 1570. I know what they did in 1150.
8 MR. LONG: Okay, I was going to tell you what we
9 did at that point was essentially the same thing. At that
10 point in time, we were basically trying to extrapolate from
11 1150.
12 MR. CATTON: Oh, okay. Okay.
13 MR. LONG: 1150 had brought up.
14 MR. CATTON: No, I understand. I understand.
15 MR. LONG: Okay, since that time, when I try to do
16 Farley, I try to take into account something about the
17 distribution of temperature in the tubes, and I guess, we'll
18 get into this later, because Charlie is going to talk about
19 how we do the modeling of the tube temperatures. But the
20 distribution of the temperature -- RELAP does not really
21 attempt to calculate the average temperature in the bundle
22 and the hottest temperature in the bundle. MAP does make an
23 attempt at that. But they do it with an average temperature
24 and then they make a guess in plume assumption.
25 MR. CATTON: In either case, either MAP or RELAP,

1 they're based on inadequate information. So, I'm just
2 curious as to what you do about that, when you go into your
3 world of risk.
4 MR. LONG: Okay. It probably would be better to
5 ask me this when we get to talking about what I do for
6 Farley, because I did try to capture that when I did Farley,
7 and it would help if Charlie had a chance to do his
8 presentation first.
9 MR. CATTON: I don't want to bore everybody else
10 here, so I can wait.
11 MR. LONG: I recognize the problem. I was
12 afflicted with this problem a year ago, when I was really
13 hard put to figure out what to do with it. So I'd be glad
14 to explore it as soon as we get everything on the table.
15 ATLAS, fairly quickly, the ATLAS is a fairly gross
16 model. It assumes that if you exceed the level C service
17 pressure for the reactor coolant system that something
18 terrible will happen and you will damage the core. We
19 looked at ATLAS events in the Surrey model to try to figure
20 out if they were part of the high dry. It looked like most
21 of them weren't, although if you had a failure of all aux
22 feed, they could be. We had some thermohydraulic cases run.
23 Len Ward ran some for us where we actually sequentially
24 ruptured tubes when we reached certain pressures. And lo
25 and behold, it lowers the peak pressure in the ATLAS. They

1 would have to be fairly weak, tubes, because in the ATLAS
2 situation, you probably have the main steam system up near
3 the safety valve set points so it's a thousand plus PSI.
4 The primary system is, if it only goes to 3,200 PSI, you're
5 maybe at 2,200 pressure differential across the tubes.
6 That's not the full main steam line break pressure
7 differential. Now, the ATLAS pressures aren't limited to
8 3,200 PSI. They may go higher. What we assumed was the
9 potential for getting core damage if you went above 3,200,
10 and the potential for rupturing the tubes. And if you get
11 up -- in the way we did it in 1570, you'd add five percent
12 bypass -- five percent of your ATLAS core damage frequency
13 to the bypass if you were just blowing the tubes from
14 pressure effect alone. Since you, 3,200 PSI is a little bit
15 below what was giving us five percent conditional rupture
16 probability. We weren't quite sure where we were in the
17 average rupture probability for all ATLAS sequences. But it
18 looked like, given the frequency of the ATLAS sequence being
19 low enough it wasn't really contributing much to our answer.
20 CHAIRMAN POWERS: I'm thinking about overpressure
21 events -- you looked at accidents that initiated
22 overpressure events. I wonder have you thought at all about
23 an event that involved the relocation of fuel in the water
24 producing a shock wave?
25 MR. LONG: I've thought about it. We haven't

1 tried to calculate one yet. The -- that's one of the things
2 that gets you way out in the accident, so that if -- what
3 you'd have to do to get to where you're talking about is to
4 somehow have gotten the RCS out to where you have major
5 relocation into a pool of water on the lower head, and not
6 have a very large hole in the RCS that would, you know,
7 pretty much allow that wave to--
8 CHAIRMAN POWERS: As an ardent baysian, of course,
9 you see this as an extraordinarily likely sequence?
10 MR. LONG: I'm sorry. Say this again?
11 CHAIRMAN POWERS: As an ardent baysian, you see
12 this as a fairly likely sequence, right?
13 MR. LONG: I'm not a baysian. I hate to tell you.
14 CHAIRMAN POWERS: Just PRA, and he's not a
15 baysian.
16 MR. LONG: No, I get nervous when I see people say
17 we haven't had a steam generator tube rupture yet. So our
18 probability is lower than those other guys. We see those in
19 our submittals.
20 CHAIRMAN POWERS: Well, you have had a core melt
21 accident in which you relocated fuel and or water fuel, or
22 plenum with no -- with the system pressurized?
23 MR. LONG: With the system pressurized?
24 CHAIRMAN POWERS: With no effect on the steam
25 generator tubes?

1 MR. LONG: I guess the point is--

2 CHAIRMAN POWERS: No exploding, either.

3 MR. HOLAHAN: And when the system is at pressure

4 it's probably less likely to have such a--

5 MR. LONG: So people claim.

6 CHAIRMAN POWERS: It's a -- one to push that

7 database very hard.

8 MR. LONG: Let me tell you how far we've gotten in

9 the thought process on this. Frankly, we don't think our

10 models are very reliable out that far. But to try to keep

11 the RCS at high pressure, you know, up around the 2,200 or

12 whatever safety valve set points that far into the accident,

13 you're really saying that you haven't creep failed anything

14 first. And it looks to us like you probably would. So we--

15 CHAIRMAN POWERS: I mean, I've got a -- I've got

16 one accident, which I melted fuel and PWR, and it didn't

17 creep rupture anything. Well, it did a couple of spiders up

18 in above the fuel.

19 MR. LONG: Okay, it also didn't heat up the steam

20 generator tubes.

21 CHAIRMAN POWERS: That's also true.

22 MR. LONG: Right. Anyway, it apparently relocated

23 some fuel into water. I understand TMI has had a hard time

24 being simulated, and it wasn't very cooperative in being

25 able to be simulated by RELAP. But to try to tell you as

1 far as--

2 CHAIRMAN POWERS: But we could put out a generic

3 letter -- one must only have severe accidents that are

4 easily simulated by RELAP then.

5 MR. LONG: But seriously, we did -- we have had

6 what probably amounts to more or less to a bull session

7 about this. We've tried to think about it. And this is as

8 far as we got; that we thought that if we really had the RCS

9 at fairly high pressures that what would happen would be we

10 would creep fail something before we, you know, relocated a

11 lot into a, you know, a pool of water in the lower head. We

12 thought if we had depressurized substantially, hopefully

13 there would be some hole. If you pressurize, I understand

14 the probability of getting a steam explosion is higher,

15 right.

16 CHAIRMAN POWERS: Yeah, there is -- I mean, what

17 -- the conventional wisdom is that triggering steam

18 explosions becomes increasingly difficult with increasing

19 pressure to the point that the trigger is equivalent to the

20 yield, so--

21 MR. LONG: Right.

22 MR. HOLAHAN: Some say.

23 MR. LONG: If the majority voted to that extent,

24 yeah.

25 CHAIRMAN POWERS: The -- I mean, the database is

1 based on some droplet tests, triggering tests. And there --
2 and people smile about those and say, okay, I think I
3 understand this, why it might be. Except there's this
4 obnoxious Winthrop experiment where they pressurized and it
5 damaged -- the resulting explosion damaged their facility
6 and they had to quit doing things. So it's a mixed bag, and
7 I understand that some of the experiments that they had done
8 in recent past in, I guess, Germany or Europe anyway, that
9 they too began to question this pressure inhibits triggering
10 concept. It's not -- the problem is that we just don't do a
11 lot of steel and aluminum tests in high pressure systems,
12 where the vast majority of our database on steam explosions
13 come from. So--
14 MR. CATTON: That's the history of the steam
15 explosion, isn't it?
16 CHAIRMAN POWERS: Oh, yeah.
17 MR. CATTON: You develop convention wisdom, then
18 you blow it up.
19 CHAIRMAN POWERS: That's right. Yeah, I mean,
20 that's -- I mean, that's certainly the history of the copper
21 industry and the aluminum industry that they get some idea
22 of what prevents these things. They pursue that idea until
23 the next explosion and then they host another conference and
24 sponsor more research.
25 MR. LONG: Well, to try to tell you where we got

1 to -- we were thinking about what would happen if you had
2 deck tubes and a big enough hole in the RCS to have
3 successfully depressurized it, and then you drop the
4 relocation into the pool and created some sort of pressure
5 pulse. It's not clear to us exactly what the temperature of
6 the tubes would be at that point, because when you've lost
7 the density in the RCS, even if you've heated the tubes up,
8 they probably cool down some just from transfer of heat to
9 the rest of the structure. But as long as the secondary
10 side was somewhat intact, it doesn't look like you would
11 rupture the tubes and raise the pressure in the steam
12 generator high enough to open safeties. So, the other part
13 of it is you should then go back to something that looks
14 like containment pressure. So even if you fail the tubes,
15 it's not clear you create a very substantial release to the
16 environment from that failure of the tubes at that time.
17 Now, it's really -- we haven't thought about it
18 beyond there. I -- we're having enough trouble with the
19 things we are trying to think about very hard is the best
20 thing I can tell you.
21 Let's see.
22 CHAIRMAN POWERS: Well, I'm encouraged that you're
23 thinking about this thing before you gain a great deal of
24 solace in saying that I want to creep rupture myself out of
25 this -- out of this problem is to do remember that TMI

1 didn't creep rupture anything. And we didn't heat up the
2 steam generator tubes, either. But is there something in
3 between those two?
4 MR. LONG: We have tried to ask ourselves some of
5 those questions. TMI was sort of an intermediate pressure
6 LOCA. It wasn't sitting on the safety valve set point,
7 because it was stuck open. Yet, it wasn't down to where the
8 accumulators would come in, either. And in the license
9 application that Arkansas submitted last March, they tried
10 to simulate this by just lowering the safety valve set point
11 to 1,400 PSI and running that for a bunch of cases. Well,
12 the difficulty is they did that earlier in the, you know,
13 the transient, so they created all their loop seals,
14 saturated at 1,400 PSI, and they kept it there.
15 When we, instead, put -- started sticking safety
16 valves open later in the transient and depressurizing
17 continuously until something evaporated and created more
18 pressure, it got to be quite more interesting, and I guess
19 we can show you some slides, if not if you need to. But it
20 turned out when you opened the hole and how big the hole
21 was, even though we just restricted ourselves to holes in
22 the top of the pressurizer, it would still give you some
23 forced flow past the surge line. It still gave you a
24 protracted accident, and some clearing and reforming of loop
25 seals so you were getting -- as some of that water was

1 evaporating and getting to hot metal, you would get pressure
2 pulses and things did not look real well behaved. The best
3 thing I can is that there's a whole very poorly charted
4 territory there that we don't think we can really give you
5 the answers for yet.
6 You asked a question about risk metrics, and I was
7 assuming this was -- should we use delta LERF or go to human
8 health effects from the releases. So I wanted to give you a
9 few thoughts on that. If that was not the question, you
10 should correct me soon.
11 We -- we're not really sure what the definition of
12 LERF is because it seems to change. But -- so it's not
13 really clear if steam generator tube failures leading to
14 core damage by various paths do exactly or do not exactly
15 meet the definition. In doing the licensing work, we've
16 tried to say, well, if it doesn't quite meet the definition,
17 but it's close to it, it's sure a lot closer than continuing
18 to accident source term. We're going to treat it as LERF.
19 So pretty much anything that looks like the secondary site
20 is open when the core is being damaged and the tubes are
21 pretty much from primary to secondary, we're going to treat
22 as LERF, for licensing purposes.
23 If we try to go to the full level three
24 consequence calculations, we still have some problems
25 getting there from what we know today. We really haven't

1 fully evaluated the effects of the RCS blow down through the
2 fault at steam generator, and the -- right now, the tube
3 temperatures are calculated as if there's no net flow out of
4 the generator to the secondary, so we have a mixing that's
5 assumed from the 1/7th scale test that's in the inlet
6 plenum, and that keeps the temperature down to the tubes;
7 that we talked about this, I think, on Wednesday a little
8 bit that if you have some substantial flow out of the tubes,
9 you are no longer forcing fluid back into the inner plenum
10 from the cold side. You're sucking it out of both sides,
11 and the mixing will probably go away. The tube temperatures
12 will probably go up quite a bit, and it's not really clear
13 what you're doing to additional failures of the tubes.
14 We've talked a lot about jet cutting, and we think if it's a
15 little leak, probably we're not in a jet cutting regime.
16 It's still not quite clear what happens if the tube that
17 you're -- is about to melt that you're squirting fluid on
18 across the way.
19 So, we really haven't defined the size of the hole
20 between the primary and the secondary as you progress
21 through an accident where you're really depressurizing the
22 RCS into the secondary. So that makes it very difficult to
23 find the flow rates in the secondary side--what the
24 velocities are going to be, what the temperatures will
25 become, what the deposition rates would be for the nuclides

1 that are transported through there. So it's very hard to
2 define a source term that is really applicable to these
3 accidents once you've decided that the secondary is really
4 becoming opened in a gross way to the primary. And for that
5 reason, we don't think we're really ready to try to go to a
6 level three until we can get to some of these, you know,
7 physical phenomena better at hand, if we ever do. The other
8 part of it is, if we did go to level three, it's not really
9 clear what the acceptance criteria are for the consequences.
10 Do we have a safety goal policy statement that has numerical
11 objectives for close-in populations, for one-mile for prompt
12 fatalities, and ten miles for, you know, latent effects like
13 cancer. But the bulk of the health effects may occur beyond
14 ten miles, especially if these things are late enough to
15 allow for evacuation, and many of them would be. So,
16 there's an issue of comparing what to what.
17 CHAIRMAN POWERS: I guess the reason -- real
18 question that we were asking here is there anything about a
19 basis coming out of the steam generator, secondary side,
20 especially large releases with bigger things -- a
21 substantial amount of material out there. It would change
22 our general view that LERF is a good surrogate for the
23 safety goal policy statement.
24 MR. LONG: You say is there anything unique about
25 them? I mean, they're different from what you would have

1 from a crack in the containment or openings around
2 containment penetration bellows or something of that sort in
3 the sense that you have smaller volumes with more structure
4 to be transited. I'm not an expert in that area, and I
5 don't see the person that I would ask that ask that question
6 here. I don't know what to say about the difference in
7 terms of the transported radioactive material. In terms of
8 timing, you can calculate when you think the releases would
9 start to occur, and depending on the size of the leak from
10 the primary to the secondary, it may be quite late in the
11 process, so there may be something like a not early large
12 release that would be a better comparison. And I know for
13 the boilers, there's an issue of late failure of containment
14 that is also sort of in this category.
15 CHAIRMAN POWERS: They -- I mean they have a
16 long-term station blackout. It's kind of funny beast to
17 deal with. It seems to me that the real concern is that
18 they could be very early in the accident sequence.
19 MR. LONG: These releases?
20 CHAIRMAN POWERS: Yes.
21 MR. LONG: Certainly a fast station blackout, you
22 know, could be pretty early. And if you could get to a very
23 large -- you know, LOCA outside containment due to something
24 like the wild and wooly main steam line break with the
25 massive tube ruptures or leaks that could be fairly early,

1 too, especially if you had any failures in ejection
2 processes. Right now, we model them as if everything works,
3 and you've got a -- you know, flow out the RWST. So,
4 there's a wide range. I know a lot of the IPEs originally
5 came in with core damage sequences not counted because they
6 resulted in core damage after 24 hours for spontaneous leaks
7 -- spontaneous ruptures, I mean. So, in that regard, it's
8 late from evacuation standpoint, but it may still be early
9 from the standpoint of time for settling radionuclides in
10 the system. So in that regard--
11 MR. HIGGINS: Steve, this is a -- maybe you
12 haven't done this, but maybe get your opinion. If you took
13 the end of site -- a typical end of cycle leakage estimate
14 from 9505.
15 MR. LONG: Okay.
16 MR. HIGGINS: And you ran a one of these risk
17 metrics on it. A delta LERF. Which region of break I.1.174
18 would you fall into in evaluating that change?
19 MR. LONG: Okay, let me answer part of that first,
20 because you said region, that brings me into a couple of
21 different parameters at the same time. Research did run a
22 case where they assumed a 100 GPM leak from primary to
23 secondary at the time that essentially has started. And
24 they ran it all the way through with melt core, including
25 the containment. And they allowed the failure in the

1 containment by the surge line failure to, you know, occur on
2 the model as opposed to keeping it from occurring and seeing
3 how it long the tubes to fail. So what you really do is
4 once you breach the RCS pressure boundary in the
5 containment, you drop the driving force of the -- you know,
6 pushing the radioactivity out the hole in the steam
7 generator tubes. And that drops the dose to the public
8 quite a bit. So Charlie's going to have to see if his
9 memory is better than mine maybe if he gets up here, but it
10 seemed to me for 100 GPM, primary to secondary leak rate
11 size hole, assuming that hole does not become any larger
12 during the accident, and the secondary was open, Charlie, we
13 ended up with something like a factor over what was assumed
14 to be a contained accident. Is that right? We can -- and
15 this was assuming more than the -- 1150 assumed more than
16 tech spec value of leakage from the containment to the
17 environment. So that's also a little bit of a shaky
18 baseline.
19 But it did not look like it got you into the LERF
20 range, if that was the size hole, and you knew that having
21 that size hole did not alter the accident so that the
22 failure was still into the containment, and the reason is
23 that you're not very far into the core damage phase of the
24 accident before you relieve the pressure on the -- you know,
25 the tube and stop driving so much through the tube wall.

1 Now, when you're asking where does that put me in
2 -- Reg Guide 1.174 regions--
3 MR. HIGGINS: Yeah, whether or not you cross over
4 into above a ten to the minus sixth change in LERF or--
5 MR. LONG: What I'm saying is it wouldn't be a
6 LERF, so you'd be doing it on core damage frequency.
7 So I wouldn't think that you would, and I'd have
8 to first ask what am I starting with from core damage
9 frequency.
10 MR. HIGGINS: Okay, that's good enough.
11 MR. LONG: Okay.
12 MR. STROSNIDER: This is Jack Strosnider. I would
13 like to add one observation there, and I think you know --
14 you did -- it's probably a reasonable question to say what
15 region would you be in in Reg Guide 1.174 to talk about the
16 delta. That means you have to understand what the
17 probability of tube rupture was before the generic letter
18 was implemented. We don't have a good handle on that, but I
19 think, you know, it's -- it wasn't assessed specifically,
20 but as I indicated yesterday, if you look at what people
21 were doing before generic letter 95.05, before the voltage
22 based criteria, they were attempting to size these defects.
23 And we talked yesterday about, you know, the ability of NDE
24 to size defects. And, of course, this was back before some
25 of the methods that are available today were available. So

1 I would just suggest, and this is just my opinion that the
2 probability of leakage from one of those tubes prior to
3 95.05 wasn't zero. Alright. So, that's the delta you'd
4 have to assess. And we don't have a, you know, quantitative
5 answer to that, but I think you need to consider where we
6 started and where we went to.
7 MR. LONG: If it's not zero, it's pretty close.
8 MR. KRESS: Yeah, but the real delta I think to
9 not be interested in is the thermally induced failure of the
10 steam generator tubes so that it becomes a large leak and
11 what's the probability of that compared to the probability
12 of pulling the search lights.
13 MR. LONG: I agree, and I think that 95.05 has no
14 effect on those cases, because they're not the vulnerable
15 parts.
16 MR. KRESS: I think I agree with you. It doesn't
17 matter whether you had bad tubes or good tubes, it will go
18 about the same time, I think.
19 MR. LONG: Well, I'm not prepared to say that.
20 What I am prepared to say if something goes in the steam
21 generator, I don't think it's the very short cracks
22 underneath the tube support plates that were allowed to stay
23 from 95.05.
24 MR. KRESS: I hear you. That's why -- that's why
25 I say it doesn't matter whether it's good tubes or bad

1 tubes. They both go about the same time.

2 MR. STROSNIDER: In the for what it's worth

3 department, when I presented, when we had the discussion

4 with CRGR on generic letter 95.05, I suggested that, in

5 fact, 95.05 could be improving the situation versus what

6 people were doing in the past. And I still -- I still think

7 that. It got a little bit of debate, but nonetheless I

8 think that sort of puts it in perspective.

9 MR. LONG: Well, it certainly initiated things

10 like, you know, condition monitoring and -- you know,

11 operational assessment processes, that I think have been a

12 big help.

13 I'm a little bit ahead of the agenda here by going

14 into the risk metrics before some of the other subjects I

15 have on, so at this point, I think probably I want to put up

16 the thermal hydraulic calculational part, if Charlie's

17 ready.

18 MR. TINKLER: I'm Charles Tinker, from the Office

19 of Research. The objective of my presentation is to briefly

20 review the severe accident analysis of--

21 CHAIRMAN POWERS: Turn things, the red light comes

22 on. Dead battery, again?

23 Sam, check the switch on the bottom.

24 MR. TINKLER: Oh, there we go. That was it.

25 Gentlemen, I'm going to have to bring my reading glasses to

1 the -- again, I'm Charles Tinkler from the Office of
2 Research. The objective of my presentation this afternoon
3 is to briefly review the severe accident analyses, and its
4 underlying bases that was used to evaluate the
5 thermohydraulic boundary conditions that might be seen by
6 steam generator tubes during a severe accident. And the
7 focus is on thermally induced failures of steam generator
8 tubes.
9 MR. KRESS: With what purpose in mind, Charlie?
10 MR. TINKLER: Well, the reason we e did these
11 calculations was in support of NUREG 1570 to look at things
12 like conditional failure probability of tubes during some of
13 these kinds of accidents. And actually, I kind of
14 remembered our numbers of condition tube failure
15 probabilities, but they were in the context of flaw
16 distributions, typical average severe flaw distributions in
17 plants.
18 MR. KRESS: Yeah, the reason I asked the question
19 though is are you looking to see if there's a significant
20 risk associated with this that we have forgotten to analyze
21 before so that it might be worthy of looking at a back fit
22 or something like that?
23 MR. TINKLER: Well, I think the idea was to look
24 at incremental risk from changes in the steam generator tube
25 criteria.

1 MR. KRESS: These are 95.05 incremental risks?
2 MR. TINKLER: No, I don't think it was -- I don't
3 think it was in connection with 95.05, but we looked at it,
4 for example, on electrosleeves.
5 MR. KRESS: Electrosleeves. Yeah, I remember
6 that.
7 MR. TINKLER: Whether was there -- was there any
8 incremental risk by adopting the electrosleeve repair
9 process. Did we increase the probability of a thermally
10 induced tube rupture, and my own sense was that in the NUREG
11 1150, there wasn't as much focus on the sequences that
12 involved the secondary side depressurization, which is yet
13 another failure and makes the overall sequence probability
14 smaller, but there wasn't quite as much attention as we're
15 devoting now to those sequences that involve the additional
16 failure of the secondary site to remain intact and at
17 pressure. Because that has a two-fold effect, and I'll talk
18 about this more. It obviously increases the delta p across
19 the tube, but it also increases the thermal load on the
20 tubes, because the reduced pressure on the secondary side
21 provides a smaller heat sink in terms of the steam on the
22 secondary side, so you -- in our calculations, we can
23 increase the temperature of the steam generator tubes by on
24 the order of 100 degrees K -- between the pressurized
25 secondary side and a depressurized secondary side. And that

1 makes a fair amount of difference in terms of the thermal
2 loading on the tubes.
3 Along the way, I hope to address a number of
4 issues that have been -- that have been raised for a number
5 of years now, and some of which are repeated in the DPO.
6 I don't -- I'm going to skip -- I have lots of
7 viewgraphs, so I'm going to skip through some of them. You
8 can see the outline. We've talked -- we know what the issue
9 is. To point, too, that natural circulation and transfer of
10 heat through the loops of an RCS was identified some number
11 of years ago--generally, it was thought to be a good thing.
12 Gets heat away from the core. Distributes it through the
13 system. It allows for the fortuitous depressurization of
14 the system to prevent bad things like high pressure melt
15 ejection and DCH and things like that.
16 But if you depressurize the secondary side, by
17 having a secondary side safety stick open, then you do
18 produce a challenge to the steam generator tubes.
19 And this is the cartoon that we normally show to
20 represent the natural circulation paths. I'm going to
21 deviate a little bit just because has been raised a number
22 of times. But the question often comes up, we produce all
23 these calculations that show counter current natural
24 circulation and creep rupture. How come it didn't happen to
25 TMI? Briefly, there are a few key factors that influence

1 natural circulation. First and foremost is the pressure in
2 the system. Higher pressure systems produce greater natural
3 circulation. Higher density flow to convect heat away from
4 the core. It also produces greater density differences, so
5 it's two-fold effect.
6 The RCS configuration. The U-tube configuration
7 steam generators are, by their nature, more likely to draw
8 flow than the once-through steam generators. It is very
9 difficult to get steam to go down through a once-through
10 stream generator and back up after it's dried out. It
11 doesn't happen. The tests at the University of Maryland
12 show that you can't get natural circulation so that big heat
13 sink out there, isn't there. So you have nothing to draw
14 flow away from the core. So you produce a weaker natural
15 circulation pattern. They do see natural circulation in the
16 hot lake, but it's a reduced effect compared to this.
17 Core blockage. If you form blockages in the core
18 region with crossed around them, there's no way to get from
19 inside that material out into the loops. And if you can
20 intermittently inject water at various times during the
21 transient, and float up over the core, like turning on the
22 2-B pump at TMI, you shut off natural circulation. Goes --
23 there's no hot core. You've covered it with water.
24 MR. KRESS: So, it's not surprising TMI.
25 MR. TINKLER: Well, TMI, if you look, they had

1 only a few periods when they could have gotten natural
2 circulation. And this shows -- this initial -- this is the
3 initial core heat up. This is turning on the 2-B pump, and
4 you can see the water level is rising back up during those--
5 MR. CATTON: They never did serve the loop seal,
6 did they?
7 MR. TINKLER: Well, when they turned it on -- they
8 might have cleared it briefly, but it refilled quickly.
9 Because if you got a loop seal, you can't get it. You have
10 to -- well, you can still get counter current, but counter
11 current--
12 MR. CATTON: Where's it going to go, to the top of
13 the candy cane and back?
14 MR. TINKLER: Yeah, that's all it's going to do.
15 MR. CATTON: That's all it's going to do.
16 MR. TINKLER: And also, at TMI, the pressure's
17 low. They had a PRV that was leaking.
18 MR. CATTON: The U over tube is too small to get
19 any recirculation within it. So--
20 MR. KRESS: With the candy cane, I'd be very.
21 MR. CATTON: You're just dead in the water.
22 MR. TINKLER: You can get a little bit in the
23 candy cane. But it's not a vigorous natural circulation,
24 and during that first large period where natural circulation
25 could have occurred, the pressure in the system is low. No,

1 this is a RELAP calculated pressure, but I do -- I -- we're
2 pretty good on -- you know, everybody's pretty good on
3 pressure. But RELAP, it made a loop. We've had a long
4 time. But we do this calculation pretty good.
5 And if you look at TMI during this initial period
6 here, this initial period, the pressure in the system is
7 quite low, and it's generally acknowledged that once you get
8 below about eight MPA, it's hard to get a lot of natural
9 circulation and convect heat away. So I know I was asked
10 that question quite some time ago, and I generally refer to
11 deviations from the typical severe accident, okay. And
12 there were deviations from the typical severe accident, like
13 reflooding, but I might have neglected to mention that there
14 -- that the fundamental design doesn't lend itself as much
15 to that.
16 But it causes me to think that maybe we ought to
17 look at some of those typical TMI calculations to try to
18 focus on how much natural circulation we could have gotten
19 and see if we can match some temperatures a little better in
20 parts of the system.
21 Also, there's an A&O calculation -- some A&O
22 calculations that were recently done, and these show the
23 effect of system pressure. One's sitting at relatively high
24 pressure safe -- at the safety. And one's with a leaking
25 PRRV. And this shows just the hot leg temperature. So over

1 this -- in this initial period here, the effect of pressure
2 makes a pretty big difference.
3 It's not meant to be an exhaustive treatment of
4 it, but it at least provide a little more clarification,
5 because I would agree that if you've only had one accident
6 to look at, and it didn't produce the thing you say happens
7 all the time, it could cause you to wonder.
8 MR. KRESS: Well, Tim, I probably run the risk
9 dominant sequence.
10 MR. TINKLER: I don't want to address that.
11 CHAIRMAN POWERS: Before you go to this
12 inter-circulation through the steam generator, I'd like to
13 understand a little better about the free loop circulation.
14 MR. TINKLER: Okay.
15 CHAIRMAN POWERS: When Steve was talking earlier,
16 I got the impression of an increased interest in this and
17 that it introduced an enormous amount of complexity into
18 this situation.
19 MR. TINKLER: Well, the loop seal clearing is --
20 it's a -- you know, first you -- you got to do more than
21 clear the loop seal. You also got to get the water level
22 below here. Okay, the down comer skirt. Because if all you
23 do is clear this, but you don't clear this path.
24 MR. KRESS: That's another loop seal.
25 MR. TINKLER: That's another loop seal. Right

1 here. So, but now we're able to clear both of them in a
2 number of calculations as a result of boil off and just
3 general water dropping in the core. And when that happens
4 you produce full loop circulation. And the key is what's
5 going on in here, because when you produce full loop
6 circulation, you don't get any cold flow returning through
7 the steam generator to dilute what goes into the tubes.
8 Another way to look at that is turning to page 17. This
9 shows temperatures around the loop at the time that we
10 normally predict surge line failure for Surrey. And if you
11 look at the temperature coming in from the hot leg, the
12 1,500 degrees K, the reason we don't instantaneously fail a
13 lot of tubes real quickly is because it's being mixed with
14 cold flow returning back through the steam generator tube
15 bundle. Okay, it's being mixed and diluted. And the reason
16 it's being mixed and diluted is because we have a loop seal.
17 If we didn't have a loop seal, it wouldn't be quite this
18 high, because there would be other things going on. But
19 we'd have a whole lot higher temperature passing through the
20 steam generator.
21 So when we do calculations where we produce loop
22 seal clearing, the issue is whether or not the pressure in
23 the RCS has dropped low enough at the time a loop seal
24 clearing occurs, because if it hasn't dropped a lot, we
25 predict failure of pristine, intact unflow tubes.

1 MR. KRESS: How good are you at predicting when
2 the loop seal clears?
3 MR. TINKLER: Well, we think we can predict loop
4 seal clearing reasonably well. It's a question--
5 MR. KRESS: When you have three loops?
6 MR. TINKLER: Well, it's the question of whether
7 or not we can predict which loop seal clears.
8 MR. KRESS: Yeah, that's the question I was really
9 asking.
10 MR. TINKLER: And we don't believe that we have
11 enough confidence in our prediction of which loop seal
12 clears, so when we approach this probabilistically in 1570,
13 we assumed an equal probability among the loops. We didn't
14 -- because we calculated loop seal clearing in some cases,
15 and we typically calculated in the loop where the safeties
16 haven't stuck open on the secondary side.
17 MR. KRESS: And if you're in a loop that doesn't
18 have the surge line?
19 MR. TINKLER: Right, it was a loop that didn't
20 have the surge line, and it was loop where the secondaries
21 didn't stick open.
22 MR. KRESS: Yeah.
23 MR. TINKLER: And if you're looking at a loop
24 where the secondaries didn't stick open, these sequences
25 where loop seal clearing typically involve some

1 depressurization of the RCS, because you're boiling water
2 out of the loop. That's what clears it, and in those
3 sequences we actually had a higher pressure on the secondary
4 side than on the primary side. Okay. So we wouldn't have
5 predicted failure. But for 1570, we ignored that. We
6 assigned an equal probability to clearing these loops, even
7 though we always predicted it to occur in a loop that --
8 where the secondary side was not depressurized. So--
9 MR. KRESS: But if the secondary side is
10 depressurized, and even if you were in the leg where the
11 surge line was, it -- I was under the impression that you
12 were -- your calculations would almost there at times show
13 that you failed the steam generator before the surge line
14 under those conditions.
15 MR. TINKLER: If it's a loop where the secondary
16 side is not depressurized, no.
17 MR. KRESS: That's not true if it's not
18 depressurized.
19 MR. TINKLER: That's not true, because typically
20 these sequences with loop seal clearing involve some
21 depressurization of the RCS, of the primary side, so you're
22 -- those will be loops where the secondary side will be at
23 1,000 and the primary side will be at 600 or 800. So we
24 can't buckle these tubes, you know. We predict they're hot,
25 but they won't fail.

1 MR. KRESS: A different failure mechanism in that
2 direction.
3 MR. TINKLER: Because the pressure is the other way
4 now on those cases. But when we did it, when we looked at
5 for assessing conditional tube failure probabilities, we
6 ignored the fact that we were actually predicting it in the
7 other loops and assigned a uniform probability to its
8 occurrence, because there is considerable uncertainty as to
9 when you predict loop seal clearing and in what loop you
10 predict it to occur.
11 MR. KRESS: That's what I thought.
12 MR. TINKLER: That is true. And it was a dominant
13 -- it was a dominant contributor to -- I believe -- tube
14 failure probability. It was the big deal.
15 MR. KRESS: That's what I was -- I was under the
16 impression of, too.
17 MR. TINKLER: That is correct.
18 CHAIRMAN POWERS: When you say the pressure is --
19 gets with the secondary sides still pressurized, and the
20 pressure in the primary is now below the pressure in the
21 secondary, when does accumulator dump occur? And when it
22 does, do you then Jack the pressure back up?
23 MR. TINKLER: Well, in some sequences where we had
24 -- where we were modeling reactor coolant pump seal leakage,
25 you would see some cases where, when we got down to

1 accumulator set point, for example, we'd get some flow being
2 driven into the steam generators, and that would cause them
3 to, in some cases, cause those tubes to heat up fairly
4 substantially. But typically speaking, reactor coolant pump
5 seal leakage and leakage in general or the RCS, unless it
6 produced loop seal clearing generally didn't cause a
7 problem. If it produced loop seal clearing, then it did,
8 because we gave it equal probability. But there is a nuance
9 associated with depressurization, where you get accumulator
10 injection and then you force steam flow into the steam
11 generator, okay, without the benefit of a lot of mixing,
12 because then you're -- then you have almost -- you know, in
13 those cases, you force it through both paths of the hot leg.
14 So those cases did produce some more, but it's a relatively
15 short-lived transient where that occurs.
16 CHAIRMAN POWERS: I was just wondering if your
17 tubes were hot, and you got a dump so that it jacked the
18 pressure so that you had the delta p across, you'd just get
19 a rupture, even though it was a short transient. Well, you
20 know typically we don't show radical pressurizations on
21 accumulator injection. We get a little pressurization and
22 then accumulator injection stops. We had an issue where we
23 looked at this where we were condensing additional water in
24 the cold leg, and that was causing us to eject more from the
25 accumulators. And that's an issue we've had some

1 discussions with the industry folks, because they contend
2 that we inject a little too much water as a result of that.
3 Because they show a very smooth accumulator pressure
4 injection transients. Those are a little more spiky, a
5 little more ragged. So, but -- that is a nuance that has
6 come up in some of the calculations.
7 MR. CATTON: I don't quite understand your figure.
8 The 1504, 982, and 775, what are they?
9 MR. TINKLER: Well, these are -- these are
10 calculations of intermediate volumes in the inlet plenum,
11 okay. These -- this is, in effect, a mixture temperature.
12 MR. CATTON: So do you feed some of the tubes 1504s
13 and some tubes 9--
14 MR. TINKLER: No. No, these two streams--
15 MR. CATTON: Are mixed?
16 MR. TINKLER: Are mixed according to the mixing
17 fraction.
18 MR. CATTON: Which is?
19 MR. TINKLER: Point nine. So 90 percent of the flow
20 is at this temperature, and twice as much of it is at this
21 temperature.
22 MR. CATTON: How do you get the 982? Where does it
23 come from?
24 MR. TINKLER: The 982?
25 MR. CATTON: That's again a mixture.

1 MR. TINKLER: That's the result of 90 percent of
2 this flow being mixed with this 775, okay. See, this cold
3 flow returning through the steam generator bundle.
4 MR. CATTON: Sounds really complicated. Where did
5 you get the information to base that on?
6 MR. TINKLER: Well, this is -- these values were
7 deduced from the 1/7th scale, in effect, deduced from the
8 1/7th scale test data.
9 MR. KRESS: Yeah, I'm interested in how you
10 actually made that deduction. Did you have temperatures in
11 the -- certain tubes of the steam generator?
12 MR. TINKLER: Well, they had rotating rake thermal
13 couples in the inlet plenum.
14 MR. KRESS: Okay.
15 MR. TINKLER: And they have temperatures in the --
16 about an inch or two in the tubes, up in the tubes, in the
17 tube sheet.
18 MR. CATTON: In some of the tubes.
19 MR. TINKLER: In some of the tubes.
20 MR. KRESS: Did you have a temperature in the hot
21 leg?
22 MR. TINKLER: Oh, yes. There's temperatures
23 throughout the system. You know, in the hot leg -- in the
24 top and bottom of the hot leg.
25 MR. KRESS: And did you have a way to deduce the

1 flow rates in--

2 MR. TINKLER: Yes.

3 MR. KRESS: In the two counter current directions?

4 MR. TINKLER: Yes.

5 MR. CATTON: The flow rate was deduced by an energy

6 balance. It was not pressure.

7 MR. TINKLER: But they can do a little better job

8 up in the tube volume.

9 MR. KRESS: I was going to use the flow rate at an

10 energy balance to get the mixing fraction is what I wanted

11 to do.

12 MR. CATTON: You can't do that.

13 MR. KRESS: You can't do that that way.

14 MR. CATTON: Because it was the energy balance that

15 gave the flow rate.

16 MR. TINKLER: And, in part, the mixing fractions.

17 But there's also the observation of mixing from the thermal

18 couple data itself.

19 MR. CATTON: Well, yeah, but you see two people can

20 disagree, and we disagree. There was a meeting held at

21 Argonne, which I attended, where we discussed all these

22 things, and the people who were there was Viscanta, myself,

23 Ishi -- was Griffith there? You were there.

24 MR. TINKLER: Yes.

25 MR. CATTON: Peter Griffith.

1 MR. TINKLER: Peter Griffith.

2 MR. CATTON: And the way -- the conclusion by
3 Viscanta and myself, Griffith was kind of neutral, was that
4 you couldn't really scale this data. There were just too
5 many unknown factors. You couldn't scale it to the full
6 size. This was the conclusion of those people. Ishi felt
7 you could scale it, but his background is two-phase flow.
8 It's not natural convection, and this is the buoyancy driven
9 problem. And in the inlet plenum, it's a highly complex,
10 multi-dimensional flow. When I looked at the temperatures,
11 I could find a tube or two where the temperature was very
12 high, much higher than in any of the other temperatures. It
13 was almost as if it fingered through directly into the tube.
14 So these kinds of things never became a part of this
15 problem.

16 Well, what does all this mean? First, if there's
17 zero mixing, the tubes will surely fail. If you have high
18 mixing, the surge line will surely fail.

19 MR. KRESS: Not surely because the time and
20 temperature were still pretty close together.

21 MR. CATTON: Even then, they're relatively close
22 together, and there are a lot of things that I can talk
23 about the other side, too. The way the surge line is
24 treated, the heat transfer is probably not high enough.
25 Because unless you guys have done something different in

1 RELAP-5, you still used it as filter. And the heat transfer
2 coefficient to the surge line should be augmented. On the
3 other hand, there is some surge lines that come in on the
4 side. And if that's the case, then the surge line is not
5 going to be heated as fast. The more you move the surge
6 line down, the more buoyancy and its effect on the heat
7 transfer changes. When it's up, you get -- it's probably
8 helpful. If it's down, it's on the other side.
9 MR. TINKLER: Well, actually having a horizontal--
10 of this horizontal leg on the surge line does -- can be a
11 help, too, because it also helps establish natural
12 circulation.
13 MR. CATTON: Well, there are a lot of factors.
14 There's even the interaction between the two flows and here,
15 the divided into two pipes. What do you do with something
16 like this. I think you almost have to give it a -- unless
17 you want to do the kind of basic research that's needed to
18 address this complicated problem, you're going to have to
19 give some credibility to the fact that the mixing isn't
20 going to be what you think it is. Now, I suspect that, you
21 know, if you had to make a guess, you guess 50-50 chance.
22 Who knows where it's at? It's somewhere between zero and
23 one. And it's certainly not either.
24 CHAIRMAN POWERS: I come back to my baysian
25 instincts, even if Steve isn't an ardent baysian, I am. And

1 they got a test here that has some flaws to it. But comes
2 back indicating relatively high mixing. I don't no whether
3 it's 90 percent or 87 percent.
4 MR. CATTON: I didn't come to that conclusion when
5 I looked at the data. When I looked at the temperatures, I
6 came to the conclusion that there were some tubes that were
7 going to be fed almost directly the high temperature gas.
8 MR. TINKLER: I guess, we -- I'd have to say, we do
9 not come to that conclusion. And, you know, this Committee
10 has, I think, been provided with the results of that peer
11 review, so, you know, you can take a look to see what --
12 there were a number of discussions. I think it was nearly
13 unanimous that the tests were well designed and well
14 executed and that they indicated mixing. Now, we can argue
15 about whether or not it's 90 percent mixing fraction or 60
16 percent mixing fraction or things like that, okay, but we
17 did -- we have done sensitivity studies on these parameters.
18 I'll talk about them a little more. And you can see the
19 effect of them. Whether or not a fluid stream line can go
20 unmixed from the hot leg up into the tube sheet, I guess is
21 a, you know, is a concern that has been expressed. We don't
22 deny that at all. The general indication, though, as far as
23 we're concerned is that the data does not indicate unmixed
24 flow. Does that mean it couldn't occur under a range of
25 conditions, including tube leakage. Well, that's something

1 that needs a little more consideration. But, you know,
2 that's the general -- that's the general view we have at
3 this point.
4 My first--
5 CHAIRMAN POWERS: Before you proceed, now, this
6 peer review that you're speaking of was the same meeting as
7 Ivan was speaking of?
8 MR. CATTON: That's right.
9 MR. TINKLER: Yes. Yes.
10 MR. CATTON: We each, I guess we read the letters
11 written by the people who attended the meeting differently.
12 CHAIRMAN POWERS: Yeah, apparently so. I guess you
13 have to read them yourself to come to that conclusion.
14 MR. TINKLER: Well, you know, there is some
15 questions. For example, we can't scale, in a 1/7th scale
16 test, the exact flow conditions for a tube, because we can't
17 make the tubes 1/7th diameter. They'd be too doggone small,
18 and the hydraulic diameter would be too big, and the
19 resistance through the tube bundle would be huge. So you
20 got to have the right flow area through the -- this 1/7th
21 scale tube bundle relative to the flow area in the hot leg.
22 And you have to have the right mass. Because it's the mass
23 of steel that's actually the source of natural circulation.
24 So it's hard for us to claim that we're simulating each and
25 every tube.

1 Now, are we producing the same kind of bulk mixing
2 pattern in the inlet plenum? We think we are. The ACRS
3 what used to be the severe accident and thermohydraulic
4 subcommittee -- I'm not sure what it is now -- but we made
5 presentations where we compared frood numbers in the test to
6 the frood numbers in our code calculations, showing that we
7 were doing a pretty good job of predicting them, between the
8 plant and the experimental facility. But there are
9 undoubtedly distortions in that facility that cannot fully
10 accommodate, you know, the exact nature of mixing in the
11 tubes. But the other point I make from time to time, with
12 varying degrees of success, is that the fluid stream lines
13 are not fixed. Fluid that comes from the hot leg in a
14 single stream line, and you saw the CFD code calculations.
15 We can calculate stream lines very accurately if we want to,
16 but that doesn't mean they say; that what comes out of here
17 always goes to this one tube out of 3,000. It moves around
18 a little bit, this plume. Actually, they saw evidence in
19 the test that the tubes carrying hot flow and cold flow
20 occasionally change a lot. So--
21 MR. KRESS: But particularly if you're in a
22 transient.
23 MR. TINKLER: So if you got a stream line that's a
24 little hotter than the average, there's no reason to think
25 it stays in this tube for a particularly long period of

1 time. That plume does -- there is some oscillation to it.
2 Now if -- you know, as I say, I make that argument with
3 varying degrees of success, so--
4 But it -- the first summary is that we've used the
5 SCDAP/RELAP code to analyze this for potentially risk
6 significant scenarios. And typically, we predict the
7 failure of the hot leg or surge line before unflawed tubes.
8 We've done a number of sensitivities on thermohydraulic
9 modeling. It didn't alter the conclusion, but the margins
10 are pretty small.
11 I can skip through this example calculation if
12 we're--
13 MR. CATTON: What might be -- do you have one that
14 shows the time?
15 MR. TINKLER: Well, I can show as part of this --
16 I'm sorry, Dana, did you?
17 CHAIRMAN POWERS: Well, go ahead and answer Ivan's
18 question. But the question I'm going to ask at some point
19 in the discussion is that suppose we don't fail the surge
20 line, is there anything about -- if we do not fail the surge
21 line, you will predict a steam generator tube failure
22 someplace, at some time.
23 MR. TINKLER: Well, typically, if we don't fail the
24 surge line, the next thing that fails is the hot leg.
25 CHAIRMAN POWERS: Okay, leave them both out.

1 MR. TINKLER: Leave them both out?

2 CHAIRMAN POWERS: Yeah, let's just--

3 MR. TINKLER: Yeah, we'll fail a tube. Yeah.

4 CHAIRMAN POWERS: Okay, is there anything about
5 that tube failure that would be worsened or improved by the
6 peculiarities introduced by generic letter 9505, or is it
7 such a robust failure that it's like you're full loop seal.
8 You had failed a pristine tube just as likely or just about
9 the same time as you would fail one that's got a few cracks
10 in it?

11 MR. TINKLER: I will turn to people much more
12 qualified to comment on the nature of the failure than
13 myself. Someone in the front row back there, preferably Joe
14 or Bill, if they could comment on the nature of that
15 failure.

16 CHAIRMAN POWERS: Now, we do have.

17 MR. TINKLER: Typically, what we assume is that
18 it's a cross section of a tube for the calculation. We have
19 done some--

20 MR. CATTON: Can I help you out?

21 MR. TINKLER: Calculations of fission product
22 inventory released off site, okay. Not level three per se,
23 but fractions of our inventory.

24 MR. CATTON: Isn't 9505 restricted to that big
25 thick plate on the bottom?

1 MR. HIGGINS: No.

2 MR. CATTON: Or even the tube support plate? The
3 heat transfer to the plate is going to be enough that that's
4 going to be a cool spot along the tube.

5 CHAIRMAN POWERS: Okay. I mean, clearly we do have
6 this peculiarity of the leakage flow that can change this
7 whole picture here. But I'm going to leave that out, just
8 like I'm going to leave out all these surge line and nozzle
9 failures, and ask if there's anything -- what I'm asking is
10 how much time to devote to thinking about and reviewing all
11 of these things. If, in fact, there's -- leaving aside the
12 leakage question, right now, there's nothing, I mean, it
13 would fail if I had a brand new steam generator in there
14 with alloy 690 and no cracks, it would fail just as much as
15 it would with one that was filled with lots of non-through
16 wall, non leaking cracks.

17 MR. KRESS: I certainly believe within the
18 uncertainties of this thermohydraulic analysis, you can't
19 tell the difference.

20 MR. SHACK: There's no uncertainties. He's just
21 killed the hot leg failure and the surge line failures, and
22 the only thing that's left is whether the core will rupture
23 or that will happen.

24 MR. KRESS: No, what he's asking if there were
25 uncertainties in these things is such that maybe you do at

1 some probability fail the steam generator tubes first at
2 some probability because of the uncertainties in everything.
3 Would you have gotten the same answer whether you had your
4 tubes or not.
5 CHAIRMAN POWERS: What I know is that people that
6 do these calculations--
7 MR. MUSCARA: For that temperature that -- you
8 know, on the transient reaches 840 degrees. So a much--
9 MR. KRESS: And it doesn't matter whether they're
10 cracks or not.
11 MR. BALLENGER: I read 1,200. I mean, 1,500K,
12 1,200C.
13 CHAIRMAN POWERS: That's the gas temperature.
14 MR. BALLENGER: That's the gas temperature.
15 CHAIRMAN POWERS: It's hot stuff.
16 MR. BALLENGER: It's hot stuff.
17 CHAIRMAN POWERS: What I know is that people have
18 tried to develop codes other than the one that was used for
19 this calculation, and when they tried to model the counter
20 current flow, they have to do it the same way RELAP does by
21 putting in these figures, and things like this.
22 MR. CATTON: It depends on how much money you want
23 to spend.
24 CHAIRMAN POWERS: Well, these guys didn't spend--
25 MR. CATTON: A really good example of that was the

1 Comik School from Argonne, and the PTS issue. The whole
2 nuclear industry uses 1020 now because they don't want to
3 spend the money on the computer time. So somebody hired a
4 consultant from CHAM in Huntsville and said, gee, how many
5 would I need to really do it right. He came up with a
6 number over 100,000. So what do they do, they say, okay, we
7 don't want to that.
8 CHAIRMAN POWERS: Okay, well, there--
9 MR. CATTON: If they're willing to do that, you can
10 handle counter current flow. The problem is one of how much
11 you're going to spend on the computer.
12 CHAIRMAN POWERS: These guys, you know, they're
13 independent of these, and so they made different decisions,
14 though inherently the model is about the same. Okay, you
15 would castigate it just as much as you do this one. And,
16 but they did it differently, and, as a result, they
17 presented curves that were just like those except the labels
18 were permuted. And so I'm saying if I have that case, and I
19 assume that's reality, is there anything unusual about this
20 -- these steam generators now that we've allowed generic
21 letter 9505 -- other than leakage. We'll put that aside,
22 because we're going to get to that one a little later --
23 that have changed the positions of those curves, and I get
24 the strong feeling that to the level of detail that these
25 calculations are typically done, no.

1 MR. KRESS: That's what I feel.

2 MR. BALLENGER: I mean, is there any error. What

3 are the error bars on these numbers?

4 MR. TINKLER: Well, we're going to talk a little

5 more -- we'll get to that a little more.

6 MR. BALLENGER: I mean, that's -- if it's 200

7 degrees, and man this is--

8 MR. KRESS: Yeah, that's a very legitimate

9 question. That's why I asked him that initial question.

10 Dana, I asked him that initial question: for what purpose

11 are you doing this. And that was the reason, because--

12 CHAIRMAN POWERS: Well, I know the purpose he's

13 doing it, because we asked him to--

14 MR. KRESS: Yeah, I know, but, you know, maybe he

15 has an alternative ulterior motive, but that was my reason

16 or that question, because if you perceive there's no

17 difference, what are you going to do with those numbers? Is

18 it a new set of risk sequences that you just forgot about

19 before, and you want to see if they're important or not.

20 CHAIRMAN POWERS: Well, I think the -- I mean, the

21 issue that is very important is if we allow the leakage, and

22 we stipulate that we believe that--

23 MR. KRESS: Yeah, that may be a significant issue.

24 CHAIRMAN POWERS: Everything they told us about the

25 mixing and we stipulate that they simulate the Westinghouse

1 data out to the third significant figure, and there's
2 nothing wrong with data, and I admit that questions have
3 been raised about it, but if we stipulate that and then we
4 introduce this leakage over -- Now that's an interesting
5 issue.
6 MR. KRESS: Yeah.
7 CHAIRMAN POWERS: Then the question then comes
8 back, again, is there anything different now if you had--
9 MR. KRESS: And that is certainly different, but I
10 think what you probably will find out is if you make the
11 calculation of the risk that you get due to the -- assuming
12 the steam generator tubes fail first, you're probably can
13 make an argument of acceptable risk, but that's something
14 I'm hoping they get to.
15 MR. STROSNIDER: This is Jack Strosnider. I'm not
16 sure, I want to enter into this discussion. What I'm sure
17 of -- but I guess the one thing I would point out is, in my
18 understanding of the events being talked about here is that
19 they're not the extreme blow down events. You know, they
20 don't put those kind of loads on support plates, et cetera.
21 And we've discussed, to some extent, the pass that with
22 regard to the ODSEC at the support plates. The support
23 plates will be there, so it's not clear to me that, you
24 know, that's the location that's going to be critical in
25 terms of tube failure. In fact, I think it's probably going

1 to be someplace else.

2 MR. TINKLER: Well, actually -- but these

3 temperatures are the first region above the tube sheet.

4 MR. KRESS: Yeah, but it doesn't matter. If you

5 induce the leakage, it doesn't matter where the leakage is.

6 It's going to suck the -- you know, it's going to induce

7 some failure somewhere else.

8 MR. CATTON: It will probably suck it from both

9 directions.

10 MR. KRESS: Yeah, but--

11 MR. CATTON: If it's a big leak.

12 MR. KRESS: Yeah, it will change things markedly in

13 terms of its failure, even though you don't -- even though

14 you think the leakage is going to be, failure doesn't

15 matter.

16 MR. SHACK: Since we're firing off speculation

17 here, I'll go with Jack. I mean, if I put this thing in

18 that collar, that thing is not going to have any gross

19 failure. You know, you're going to see one of my hippo type

20 failures somewhere else in the free span of this thing. But

21 what you will get with the generic letter I think is some

22 leakage through the cracks that's, you know, on the order of

23 ten gallons under a main steam line break, which would

24 correspond to some equivalent area, which you can presumably

25 use to get a gas flow at this temperature.

1 MR. KRESS: Yeah, and the question is, does that
2 change this picture?
3 MR. SHACK: And you'll get some -- well, the
4 question is whether that additional leakage bothers you very
5 much, yeah.
6 MR. HOLAHAN: No. My answer is no. Of all the
7 things we don't know, which you hear a lot of, the effect of
8 9505 is not one of them. I think we're pretty clear that
9 9505 is the least important risk implication.
10 MR. KRESS: So I guess the real question, from a
11 risk standpoint, is whether you increase that leakage over
12 and above what you say is in 9505?
13 MR. HOLAHAN: Right.
14 MR. KRESS: Because there's some probability of
15 that being much greater.
16 MR. HOLAHAN: Right. You recognize.
17 MR. KRESS: I think that's a question that will
18 change the risk--
19 MR. HOLAHAN: Right. Approving 9505 allows
20 effectively leakages from going from one GPM to potentially
21 a little more than that. Okay. And in a realistic point of
22 view, I think maybe it wouldn't change it all. But at least,
23 to say, you know, in theory, a virtual leakage call it,
24 okay, we would allow some.
25 I think it has no effect on the likelihood or

1 consequences of tube ruptures or multiple tube ruptures for
2 any of these sequences. Zero. Minimal. Negligible. Zero.
3 MR. KRESS: I think you're probably right.
4 MR. TINKLER: I just showed this. I always show
5 this so I can overlay this other plot and show you that,
6 indeed, it's the hydrogen generation --- the onset of
7 hydrogen generation that really causes things to heat up
8 here.
9 MR. KRESS: Yeah, because that's where all the
10 energy is.
11 MR. TINKLER: That's where all the energy--
12 MR. HOLAHAN: To be fair, I didn't get to see the
13 overlay.
14 MR. TINKLER: Well, let me, actually, I always show
15 it on an expanded plot, too, because, you know, depending on
16 what part of the transient you look at it -- if you look
17 from time zero, well, it's a small fraction of the time of
18 the total transient, but if you look at when things really
19 start to happen, the time differential between tube failure
20 and surge line failure is a larger fraction of that
21 interval. Another way of looking at the margin is, if you
22 look at the time surge line failure is predicted to occur,
23 and look at the temperature of the tubes at that point,
24 that's 950 -- about 957. Now, in this calculation, we
25 predict the tubes to fail at about 1150, okay. Now, Joe, I

1 just checked with him, he said when he ran his tests, the
2 tubes failed about 1,110K. Alright, we got to stay on K
3 here. So 1,110 to 950, that's another indication of the
4 margin. We're actually--
5 MR. KRESS: Or it's an indication of the level of
6 uncertainty.
7 MR. TINKLER: Well, but it's -- I mean, you say,
8 15, 20 minutes, that doesn't sound like a lot of time, but I
9 don't know. There's 160--
10 MR. SHACK: At 160 per minute, it's a lot of
11 temperature.
12 MR. TINKLER: At 160 -- but 160, you know, 160
13 degrees sounds may be a little better when you start talking
14 about the sensitivity studies.
15 MR. CATTON: But I don't have to change the mixing
16 very much to get that curve?
17 MR. TINKLER: Well--
18 MR. KRESS: And then you divide that.
19 MR. TINKLER: Overall conclusions. Now they -- I
20 haven't proven these conclusions from the viewgraphs you've
21 seen, so--
22 MR. KRESS: These are speculating--
23 MR. TINKLER: No, these are valid conclusions. We
24 just don't have enough time to -- for me to show you all the
25 calculations. But as I said, this is worth a 100 to 150

1 degrees Kelvin in the tube temperatures, typically. I think
2 that's about -- in the neighborhood. So that's just worth
3 about 1,000 PSI across the tubes. So those two factors
4 combined make these kind of assumptions the most dominant
5 assumptions in the calculation. If the operator is able to
6 open the PORV, this problem goes away. We've done quite a
7 few calculations that show you depressurize -- you can
8 generally get down to about two and a half megapascals, and
9 that's enough for this problem to go away, if you can find a
10 way to reliably do it.
11 Pump seal leakage. It's biggest effect was on the
12 loop seal clearing, but it may have some effects on other
13 calculations, but they appear to be of less importance than
14 the pump seal leakage.
15 CHAIRMAN POWERS: Now, pump seal leakage is
16 becoming less of a problem for plants now, because they put
17 the improved?
18 MR. TINKLER: Well, we did the calculations with
19 the new -- with the distributions for the new pump seals.
20 But -- it's still a pretty high rate depending on, you know,
21 the calculations, but with -- with -- indisputably, certain
22 thermohydraulic boundary conditions and phenomenological
23 issues are important in the plenum mixing. It's clear, if
24 you don't mix at all in the inlet plenum, that makes a big
25 effect on your calculation. We think there is inlet plenum

1 mixing. Heat transfer modeling makes a difference, and loop
2 seal clearing makes a difference.
3 CHAIRMAN POWERS: Can I ask you a phenomenological
4 question? If it takes too long to answer it, tell me so,
5 because it may not be germane here. As you have that
6 counter current flow going along the pipe leading into the
7 plenum, that's modeled as a fairly smooth process. It's not
8 really. And it won't be very long smooth. Does that
9 disrupt any of this -- any of these arguments or any of
10 these thermohydraulic modeling?
11 MR. TINKLER: I'm not sure I understand your
12 question.
13 MR. CATTON: The interface between the hot stream
14 and the cold stream will be both friction and heat transfer,
15 and this will reduce the impact on the steam generator
16 tubes, and as far as I know, when we did work on it, we
17 didn't include it. And they certainly don't by sticking it
18 in pipes.
19 MR. TINKLER: No, we don't, but the observation
20 from the test data is that those streams are fairly
21 isolated, and there is not much mixing between the streams.
22 That was the--
23 MR. CATTON: It depends on the velocities.
24 MR. TINKLER: It does, but I can only tell you that
25 the general conclusion from that test data was that it is,

1 those streams are fairly well isolated. Now we did
2 calculations to model heat exchange between the two streams.
3 That makes it better. That's good for us. It lowers that
4 average temperature going into the steam generator, getting
5 a little more mixing, a little more heat transfer between
6 those two streams, lowers our peak tube temperature. That's
7 to the good, and we do calculate -- we did calculations that
8 maybe I'll get to you that will show you -- that will at
9 least show the numbers.
10 MR. CATTON: But it's kind of like Los Angeles,
11 Dana. You know, if yo fly in there, you can see the top of
12 the smog layers just as smooth flat surface. And it's
13 diffusion controlled. So whatever you do, because the hot's
14 above and the cold's down below, you transfer it from one to
15 the other, it's going to be -- I mean, everybody's flown
16 into Los Angeles.
17 CHAIRMAN POWERS: Just to be indulgent, since I'm
18 the chairman, I get to do these things.
19 [Laughter.]
20 You know, you got aerosols in the hot stuff that
21 want to go down. And they go down pretty good rate.
22 MR. CATTON: That's okay. But that's a little bit
23 different. I mean, I -- that's still a bit different.
24 MR. TINKLER: That's -- you know, I had thought
25 about it. But you know, they actually did some tests in the

1 1/7th scale to look at the effect of aerosol deposition in
2 the hot leg. They primarily looked at it from the
3 standpoint -- they didn't actually -- I take that back --
4 they didn't model aerosol deposition, they put a heat source
5 on the pipe to see if that disrupted the natural
6 circulation.
7 CHAIRMAN POWERS: Oh, and that's a good piece of
8 information.
9 MR. KRESS: I suspect you were also using steam,
10 and you got through telling us that this temperature really
11 took off when it was the hydrogen generation part, and I
12 don't know how hydrogen would behave under those conditions,
13 either.
14 MR. TINKLER: Well, we -- you know, we have
15 hydrogen in our calculations, and they did inject a simulant
16 for hydrogen in the 1/7th scale tests.
17 MR. KRESS: Oh, I didn't know that.
18 MR. TINKLER: Yeah, they had, there were five
19 separate phases to their -- you know, their high pressure
20 test program. I think one of them included a lighter gas
21 than sulfurhexaflourine. So--
22 MR. HOLAHAN: I mean, there's absolutely a minimal
23 amount of racinium.
24 CHAIRMAN POWERS: A minimal amount of what?
25 MR. HOLAHAN: Of racinium. Just thought I would--

1 CHAIRMAN POWERS: Oh.

2 MR. HOLAHAN: Throw that in.

3 MR. KRESS: That's what I was expecting, yes.

4 CHAIRMAN POWERS: It's an all steam system, so that
5 we wouldn't expect it--

6 MR. TINKLER: Actually, I thought you were
7 prompting that -- I don't know whether there was something
8 later on in this sequence that might make this sequences a
9 little different. The chimney effect if you fail something
10 and later fail the vessel.

11 Code validation. We've talked about this, so I
12 won't dwell on it, but, you know, we didn't -- we didn't
13 just start doing these kinds of calculations. We've been
14 doing them a long time. And the folks at INEL, Len Ward and
15 Darryl Knudsen, who's here in the audience today, whose done
16 more of these calculations than anybody in the world,
17 probably everybody else in the world combined, actually.
18 We've done a lot of them.

19 CHAIRMAN POWERS: I think we're willing to
20 stipulate that.

21 MR. TINKLER: Okay.

22 CHAIRMAN POWERS: I wonder if we could -- just a
23 few to -- schedule a little bit, take a recess at this
24 point, come back and discuss this effect -- the section of
25 effective leakage on inlet plenum mixing.

1 I mean, I don't want to take out things that you
2 think it's important for us to hear.
3 MR. TINKLER: No. No.
4 CHAIRMAN POWERS: But on the validation of the
5 model and the basis for it, I think -- we're willing to
6 stipulate.
7 MR. TINKLER: Sure. Okay.
8 CHAIRMAN POWERS: Those things and then move to the
9 issue that's part of our contention, which is the effect of
10 leakage on the mixing. With your indulgence, and I
11 appreciate that, we will return at a quarter after and
12 resume on this section.
13 [Recess.]
14 CHAIRMAN POWERS: Let's come back into session. I
15 apologize for interrupting your presentation, Charlie.
16 MR. TINKLER: Okay.
17 CHAIRMAN POWERS: And, again, if there is material
18 that I suggest we jump over and you think it is critical, --
19 MR. TINKLER: Well, I would just like to very
20 briefly talk about the sensitivity studies --
21 CHAIRMAN POWERS: Sure.
22 MR. TINKLER: -- that show what the effect of some
23 of these parameters that are of debate.
24 We talked about the parameters that influence
25 mixing and the temperature in the tubes. Some of the

1 parameters identified early on were the number of tubes
2 carrying hot flow, the mixing fraction, the recirculation
3 ratio.
4 We went back and looked at the range of values
5 deduced from the 1-7 scale test data and varied those
6 parameters for the calculation. Single sensitivities varied
7 over the range showed a change in the tube temperature on
8 the order of 20 degrees or less, so they didn't seem to have
9 a large effect.
10 DR. KRESS: Those are kind of weird looking ranges
11 to me, .76 to .89. How did you arrive at what to choose for
12 those? 29 percent, why not 30 or --
13 MR. TINKLER: Well, we took the numbers that were
14 evaluated from the 1-7 scale test without rounding them up
15 or down, or --
16 DR. CATTON: So there is no consideration of the
17 possibility that --
18 MR. TINKLER: They could be different.
19 DR. CATTON: Rare probability that there was some
20 error in the scale.
21 MR. TINKLER: We will address that later, and I
22 will talk about that a little later. We did some additional
23 calculations in response to recommendations made by the ACRS
24 and by the peer reviewers. They said, well, that range of
25 parameters you changed was pretty narrow, some of the

1 comments you just heard, and why don't you change a couple
2 of things at the same time?
3 So, first, we changed heat transfer coefficients.
4 And, generally, whenever we changed heat transfer
5 coefficients, it made things better, because --
6 DR. CATTON: It depends which one you change.
7 MR. TINKLER: Well, it depends which one you
8 change. But, remember, this is our base case. We only had
9 one where it went the other way, all the other temperatures
10 got lower. And that is because the environment in the steam
11 generators is nearly adiabatic. The tube, the difference
12 between the vapor temperature and the tube temperature is
13 really quite small. So we can't change a heat transfer
14 coefficient and make the tubes hotter. We can make the
15 other stuff hotter but we can't make the tubes hotter.
16 MR. BALLINGER: What you are saying is is that
17 this calculation is not -- is dominated by something other
18 than what you varied?
19 MR. TINKLER: Yes.
20 DR. CATTON: It is dominated by the mixing.
21 MR. TINKLER: Yes.
22 MR. BALLINGER: Completely.
23 MR. TINKLER: Yes. Although, if we increased the
24 heat transfer coefficient at entrances more than 1.3,
25 because you could argue that maybe that is not enough for an

1 entrance effect in some local geometries maybe, we could
2 maybe improve the performance of the tubes relative to the
3 hotleg or surge line.
4 MR. BALLINGER: But how far off could the dominant
5 thing be? What does dominate?
6 MR. TINKLER: Well, I mean if you think there is a
7 probability of unmixed flow going to the steam generator
8 tubes, you go back to that 15 --
9 MR. BALLINGER: So is there a real estimate of the
10 uncertainty?
11 MR. TINKLER: Not yet.
12 MR. BALLINGER: Like we have going around this.
13 MR. TINKLER: Not yet.
14 MR. BALLINGER: An uncertainty on that.
15 MR. TINKLER: Not yet. We will get to that. We
16 did a simultaneous change of parameters using the 5 percent
17 confidence limits from the test, the transient test, which
18 we believe to be the most relevant test for these particular
19 calculations. And when we changed everything, assumed they
20 were all independent and changed them in the worst
21 direction, to the 5 percent confidence limits, we increased
22 the tube temperature 50 degrees.
23 But that is still a mixing fraction of .73, so it
24 is not like it is -- it is not like we changed the mixing
25 fraction to zero.

1 DR. CATTON: Or even to 50 percent.

2 MR. TINKLER: Effect of leakage on steam generator
3 inlet plenum. Concern has been raised that steam generator
4 tube leakage during severe accidents could alter mixing in
5 the inlet plenum. The 1-7 scale test did not simulate tube
6 leakage. The idea is basically that -- and I had that out
7 there for so long. Well, the argument is that you have
8 3,000 tubes drawing from the inlet plenum, or, actually,
9 roughly 1500 tubes draw hot flow from the inlet plenum, and
10 maybe one of them now is drawing a lot more flow than all
11 the other tubes. So is it going to disturb that mixing
12 pattern in the inlet plenum?

13 At first observation, these tube leakage effects
14 may very likely be disbursed among many tubes. It is an
15 aggregate sort of thing, it is not one tube, and if it is
16 disbursed over the tube bundle, you would be hard-pressed
17 that it is going to dramatically influence it.

18 Leak area equivalent to a 1 GPM leak is a very
19 small fraction of the tube bundle flow and the inlet plenum
20 flow, the flow circulating in the inlet plenum.

21 CHAIRMAN POWERS: The numbers we discuss in
22 connection with predictions from one cycle to the next and
23 whatnot are all much higher than one gallon per minute.

24 MR. TINKLER: At 100 GPM, it is about 10 percent
25 of the inlet plenum flow. Now, is 10 percent spread out

1 over many tubes likely to influence the inlet plenum mixing?
2 DR. KRESS: Is 10 percent of one tube likely to
3 influence it?
4 MR. TINKLER: Well, I am not even sure that it
5 makes it worse, frankly. I mean drawing more from one
6 location may have the influence of, you know, people use
7 jets to mix things.
8 DR. CATTON: But you also have a buoyant plume
9 down there somewhere, and you might just suck away the fluid
10 that is mixing and then becomes the hot fluid.
11 MR. BALLINGER: You are not firing a jet into
12 something, you are sucking something out.
13 MR. TINKLER: Yes, I know, I got a jet coming out.
14 It is an exit jet, as opposed to -- but, so the bulk
15 velocities in the inlet plenum are not likely to be
16 influenced a great deal. The velocities at the inlet to
17 that tube, if it was one tube, would be quite higher, much
18 higher. So if the mixing occurs down deep in the inlet
19 plenum, then you might not expect the effect to be large,
20 but if the mixing occurs up close to the tube, you know, to
21 the tube sheet, it could be a more significant effect.
22 DR. CATTON: These are buoyancy driven processes,
23 and there was an experiment by Myinger some time ago where
24 it actually had to do with core melt, but just a small
25 fractional variation in the density, he put this bubble into

1 a mixture, and it just wipes everything out. You don't need
2 to do very much to completely disturb whatever the pattern
3 is that is there.
4 MR. TINKLER: Well, the general issue of mixing
5 and tube to tube variations is more problematic for any
6 codes like this.
7 DR. CATTON: You are absolutely right.
8 MR. TINKLER: So what we have laid out in response
9 to the user need received earlier this year from NRR is a
10 plan to look at this specific issue using the more detailed
11 CFD codes. We have in-house expertise that has been applied
12 to CFD codes, developed over several years, and we think we
13 can take a look at this to at least provide insights as to
14 the magnitude of the influence of this tube leakage. Does
15 it radically alter the mixing patterns?
16 And we think it is promising, we think it will
17 allow you to look at other things, too, other sensitivities,
18 the location of the entrance of the hotleg and things like
19 that on the inlet plenum mixing.
20 DR. CATTON: Do you make any distinction in the
21 calculations as a result of location of the surge line?
22 MR. TINKLER: Surge line?
23 DR. CATTON: Yes.
24 MR. TINKLER: Yes. Yes. We distinguish between
25 surge lines that are oriented with a horizontal leg or, you

1 know, an initial horizontal and vertical, or just a vertical
2 riser, yeah, we do.
3 DR. CATTON: So do you know where the interface
4 between the hot and the cold is? I guess -- no, I am not
5 sure you do unless you have a velocity.
6 MR. TINKLER: Well, I was referring to the
7 orientation of the hotleg at the inlet plenum steam
8 generator. But this, we would use this to study
9 specifically the issue of inlet plenum mixing, the general
10 issue of inlet plenum mixing and to gain insights as to the
11 effect of tube leakage on that mixing.
12 But for small leakage rates, it is clear it is a
13 small fraction. At 10 percent of the inlet plenum flow
14 rate, it may not be very clear that you will be able to
15 distinguish much difference either, especially if it was an
16 aggregate leakage over many tubes. It would be very
17 difficult to draw a conclusion about that. But if it is
18 isolated, perhaps much more so.
19 But, in any event, we do believe this will -- this
20 is, you know, these are the kinds of codes that were
21 developed for these kinds of issues, so we think it is a
22 good application.
23 CHAIRMAN POWERS: My experience with CFD codes is,
24 in truth, zero. But my witnessing of those calculations is
25 that the CFD codes do a very fine job if you have some

1 experimental data to compare against. And the kinds of
2 experimental data they compare against usually are
3 substantially more detailed than what I think you have
4 available on this mixing in the 1-7 scale test.
5 Have you given thought to the feasibility of doing
6 the experimental investigations that would be useful for
7 comparison of the CFD code analyses?
8 MR. TINKLER: We have. We have thought about
9 commissioning experiments to look at this specific issue.
10 One could conduct perhaps simpler experiments to look at
11 plume mixing in more idealized configurations, as opposed
12 to, you know, steam generators. That was just pretty
13 complicated at some level.
14 But the very first step in doing this will be the
15 validation benchmarking of the code against available data.
16 DR. CATTON: Which means Westinghouse, right?
17 MR. TINKLER: Well, which includes the
18 Westinghouse 1-7 scale test data. If I came back here, or
19 if Chris Boyd comes back here and tells you about his CFD
20 calculations, you know, a year or so from now, and he
21 doesn't compare them to the 1-7 scale test data --
22 DR. KRESS: We would wonder why.
23 MR. TINKLER: You would want to know why. So,
24 now, that doesn't say that that is fully dispositive on it,
25 so we are looking at that now, and we are in the first

1 stages of undertaking that particular activity.

2 DR. KRESS: How are we supposed to factor that

3 into our --

4 MR. TINKLER: Well, I think that --

5 DR. CATTON: You can't.

6 DR. KRESS: I know, I mean --

7 MR. TINKLER: Well, it depends on the leakage rate

8 you want to consider. If you want to consider --

9 DR. KRESS: I want to consider the leakage rate at

10 least that you have in 95-05, that it allows.

11 MR. TINKLER: Up to 10?

12 CHAIRMAN POWERS: Up to 130.

13 DR. KRESS: 130, 150, something like that.

14 MR. TINKLER: 130.

15 CHAIRMAN POWERS: They tell me they get very

16 nervous when they go to 130. Try 130.

17 MR. TINKLER: Well, like I say, 100 GPM is about

18 10 percent of the flow rate. That is not an overwhelming

19 fraction of that flow in the tube bundle or in the inlet

20 plenum. So, --

21 DR. KRESS: But it is getting up there where you

22 might think it could have an effect.

23 MR. TINKLER: It could. I guess I would be

24 tempted to say it would be a greater effect if it were a

25 point source as opposed to a spread over some large number

1 of tubes.

2 DR. KRESS: Oh, sure. Sure.

3 MR. TINKLER: Okay.

4 CHAIRMAN POWERS: Yeah. But I am not sure how
5 spread it is, because certainly they showed us an example of
6 a tube with -- my recollection is that one cycle it was on
7 the order of seven gallons per minute, and on the --
8 projecting it forward to the next cycle, some higher number.
9 So I am not sure how spread it is.

10 And on top of that, from what I see in these
11 patterns of steam generator repairs and whatnot is that the
12 most highly damaged tubes seem to come in clusters. They
13 may not be spread over the entire diameter.

14 MR. TINKLER: Well, you know, I guess I would be
15 tempted to say it would be -- it would be nice to have
16 experimental data upon which to draw some simulant fluid
17 test to look at mixing plumes with a -- while you are
18 drawing a jet off perhaps in an isolated region. That would
19 be a nice supplement to the calculations, because we will,
20 in effect, be extrapolating.

21 But the code, you know, I think that the code will
22 have the capability to look at this issue in a reasonable
23 way. But I don't know what else that I could tell the
24 committee at this point.

25 DR. KRESS: It looks like very difficult

1 experiments to do because geometry is so important.

2 MR. TINKLER: It is, it is.

3 DR. KRESS: You almost have to do a full scale on

4 those.

5 MR. TINKLER: Well, I would just be concerned

6 about preserving the general, you know, aspect ratios and

7 flow areas.

8 CHAIRMAN POWERS: But it seems to me --

9 DR. CATTON: If it were just the natural

10 circulation within the plenum region, it is just one

11 parameter, geometric similarity, and you can scale the Relay

12 number or the Grashoff number. But the fact that you feed

13 it some amount of flow, you have probably got a Reynolds

14 number in there, too.

15 Water is probably the thing to use, because you

16 can get a very high Relay number and it is probably going to

17 be turbulent and that is going to give the CFD codes a

18 headache because they still haven't really got there with

19 good turbulence models. And when it is buoyancy driven, you

20 have to treat all of the Reynolds stress terms. And it is

21 doable with CFD, there is no question. But I am not sure

22 that if you pick up a commercial CFD program, you are going

23 to get all that you need. You have a very nice paper on

24 this.

25 MR. TINKLER: The good news is it's single-phase.

1 CHAIRMAN POWERS: And it seems to me that in
2 wrestling with the experimental issues, which I think are
3 formidable, based just on the critiques that have been
4 labeled on the 1-7 scale, the overall strategy seems to me
5 like a pretty good one to start with the calculations and
6 calculate the bit, small, and in between, and things like
7 that, and at least get a feel for what's doable.
8 I think he has a real challenge in getting this
9 geometrical similitude here.
10 DR. KRESS: I do, too. I think there's a real
11 challenge there.
12 MR. TINKLER: I don't know how much -- we're
13 running a little behind.
14 DR. CATTON: The problem is that if you use a
15 simulated fluid, and you want to get a high number, you're
16 going to go to a liquid. As soon as you go to a liquid, the
17 final number gets big, and that there, the number is less
18 than one, or in gases, it's at most an order of one.
19 DR. KRESS: You can't simulate all of that.
20 DR. CATTON: That creates differences in the
21 mixing process, but it's on the conservative side.
22 MR. TINKLER: We are undertaking some new work to
23 further resolve some of these issues of uncertainty which
24 heretofore have been addressed through sensitivity studies,
25 and combinations of sensitivity studies.

1 We're going to look at different accident sequence
2 variations. An awful lot of calculations have been done on
3 -- a lot of sensitivities have been done on the Surrey
4 plant, and we're going to look more at a Zion type design.
5 We will, indeed, be looking at independent mixing
6 and tube-to-tube variations. SCDAP/RELAP will be used as
7 the principal tool for the system level analysis, okay?
8 But we will be using the CFD codes to look at
9 things like in the plenum mixing, and also tube-to-tube
10 variations, because the CFD code provides the kind of
11 resolution to look at those kinds of things in greater
12 detail.
13 DR. KRESS: Let me ask you about this new
14 research, and use an eight-letter. Does it have anything to
15 do with the DPO issue?
16 MR. TINKLER: I don't think so. I think the
17 calculations that were done for NUREG 1570, 15-20 minutes.
18 There's a kind of a sense that's, you know, that's not a lot
19 of time.
20 Things go differently than what you think, and a
21 good 15 to 20 minutes becomes minus five minutes, so --
22 And I think there's a sense that as we do more and
23 more of the assessment of delta risk and risk impacts, that
24 we need to look at the uncertainty in some of these
25 calculations, especially where the margins appear to be a

1 little small, and look at them more rigorously.

2 So, like I say, what we want to do is develop

3 distributions for these parameters, and they may go outside

4 the range of values seen in the experimental data, you know.

5 Like all distributions, we'll have tails on

6 distributions, and we'll argue about what those tails on the

7 distributions will be, and we will peer-review this, okay?

8 So, we'll have a couple of more opportunities to

9 do discuss what constitutes mixing and a characterization of

10 mixing.

11 These are the parameters we've initially settled

12 on, but we'll consider that also, I think, as part of the

13 peer review.

14 MR. HOLAHAN: I'd like to answer the question

15 about the relevance to the DPO. I think the answer is that

16 it's not related to the DPO issues.

17 If anything, this sort of analysis provides you

18 insights as to what is really important, and I think it

19 reinforces the fact that issues like 95-05 are not dominant

20 sequences.

21 DR. KRESS: Thank you.

22 MR. TINKLER: Actually, this is just a repeat of

23 the things I said just a couple of second ago about --

24 MR. HIGGINS: Excuse me. You said they were not

25 dominant sequences, but this hasn't been done yet, so what

1 do you base that on?

2 MR. HOLAHAN: I base it on that I don't see any

3 relevance to what this has shown or will show to the failure

4 of short axial cracks underneath the support plates.

5 MR. LONG: This is Steve Long to add a little to

6 this. In terms of relevance to a DPO, the user need was not

7 -- help us with the DPO; the user need was written primarily

8 because we developed a large number of issues that we were

9 having difficulty with to try to move this into

10 risk-informed regulation.

11 I will get into some of the applications when I

12 talk about some of the problems in the next slides.

13 MR. TINKLER: The Committee asked to hear a little

14 bit about fission product deposition, the issue of

15 deposition of fission products on the tubes, and that

16 contribution to heating of the tubes, specifically in

17 relationship to the work that was done and published by

18 JAERI.

19 These are points that I discussed a number of

20 years ago in presentations before the ACRS, but basically we

21 used the Victoria Code to calculate the fission product

22 release, transport, and deposition.

23 The Victoria Code is specifically a fission

24 product chemistry code with provisions for modeling

25 transport and deposition, but the thermal hydraulic boundary

1 conditions, pressures, temperatures, flow rates, are all
2 provided to it by the SCDAP/RELAP calculation.
3 And basically what you see here is that the
4 volatile fission product release is on the order of ten
5 percent decay heat.
6 That's a fairly consistent number that you will
7 see in a number of these calculations, at least insofar as
8 the early phase of core melt is involved.
9 We predicted that the fission products were spread
10 among the upper plenum, hot leg, steam generator plenum, and
11 tubes.
12 I won't dwell on that, unless there are questions.
13 Similarly, I'll skip over the Victoria nodalization.
14 CHAIRMAN POWERS: It seems to me that there was
15 one line that is pertinent from that slide on the Victoria
16 capabilities that came up yesterday. Maybe you weren't
17 here.
18 The question was raised on whether you treated --
19 you definitely were here.
20 MR. TINKLER: Yes.
21 CHAIRMAN POWERS: Treated a agglomeration and
22 thermophoresis --
23 MR. TINKLER: Yes, we do. We treat that, along
24 with laminar deposition, terminate deposition, settling, and
25 that's pipe bends, not pipe blends, okay?

1 And we can talk about some of the additional
2 models that maybe one needs to consider when they model
3 fission product deposition on the secondary side, as you're
4 concerned about the release, but that's not the issue for
5 this, but we do, indeed, model thermophoresis.
6 CHAIRMAN POWERS: One of the questions that has
7 emerged in recent years on thermophoresis is a question over
8 whose model is best. And my understanding is, without a
9 great deal of knowledge in this subject, is that the SOFARIS
10 code being developed by the Europeans uses a different
11 thermophoretic model than the Victoria Code.
12 MR. TINKLER: Well, I'm not sufficiently familiar
13 with SOFARIS thermophoresis models. I know that discussions
14 of differences in thermophoretic deposition have occurred as
15 a result of comparisons between some of our calculations on
16 FEBUS and some of the European calculations.
17 Frankly, we see oftentimes the prediction of the
18 thermal hydraulic boundary condition as being more important
19 to that comparison than the details of the thermophoresis
20 model, because we often end up with greater differences in
21 the prediction of the difference between the vapor
22 temperature and the wall temperature, okay, especially when
23 you're trying to predict deposition along a thermal gradient
24 tube where there is relatively steep gradients.
25 But, again, our steam generator tubes and the

1 vapor are about ten degrees apart. It's quite difficult to
2 imagine that thermophoresis --
3 DR. KRESS: Your use of the term, laminar
4 deposition, is probably going to overwhelm it.
5 CHAIRMAN POWERS: That, of course, raises another
6 important thing. I think we have to bear in mind that -- I
7 think there are two things:
8 I think that it is true that these calculations
9 don't have thermophoresis as a dominant deposition mechanism
10 throughout the length.
11 And the other is that theoretically, we don't have
12 a validated way of simultaneously depositing things by
13 multiple mechanisms.
14 DR. KRESS: That's exactly that each of them are
15 assumed to be independent, and I don't know really how you
16 -- you have to -- to get thermophoresis, you have to convert
17 your bulk mean temperature difference that you calculate
18 with something like SCDAP/RELAP into a temperature gradient
19 near the wall, actually.
20 And I'm not sure how you do that in Victoria. I
21 don't know what you're inputting.
22 CHAIRMAN POWERS: I think that I do know how they
23 do that. I think they have a fully developed correlation
24 and they just match them.
25 DR. KRESS: They just match each, and then they

1 get a laminar layer, and that's the distance they get for
2 the delta-T, okay.
3 CHAIRMAN POWERS: I think it's built into the code
4 to do that.
5 DR. KRESS: Okay, you just put the heat transfer
6 coefficient into the input.
7 CHAIRMAN POWERS: I think they just use a fully
8 developed flow correlation.
9 DR. KRESS: They recalculate it themselves.
10 CHAIRMAN POWERS: Yes, they keep track of it as a
11 function of the flow velocity. I do know it's fully
12 developed flow. I mean, that's about all I know about it,
13 and that raises all kinds of questions about whether you
14 should be doing fully developed flow in these things.
15 I just thought it was useful to make sure that
16 that went on the discussion record here, because the
17 question was raised yesterday.
18 MR. TINKLER: Yes, well, again, we don't see it as
19 a dominant mechanism in virtually any parts of this
20 calculation. So, we think there's an explanation as to why
21 it was cited as a dominant mechanism by others.
22 Okay, I'll get to that briefly.
23 DR. KRESS: The Japanese cited it as a dominant
24 mechanism?
25 MR. TINKLER: They cited it as a dominant

1 mechanism.

2 Why don't I just go right to that? They used

3 SCDAP/RELAP also to drive their code, which is ART, not to

4 be confused with ARTIST, but aerosol release and transport,

5 who knows. It could be.

6 CHAIRMAN POWERS: It really doesn't sound

7 Japanese, does it?

8 MR. TINKLER: No, it doesn't. They also conclude

9 that the surge line failed first, but they had a rather

10 substantial fission product heating of the tubes.

11 And the main reason is, they assumed that the

12 temperature of steam entering the tubes not quite equalled

13 -- this may be a little bit of an overstatement -- it wasn't

14 quite equal to the temperature of the hot leg, but it was a

15 lot hotter than ours.

16 DR. KRESS: It didn't have the mixing in there.

17 MR. TINKLER: They had a temperature difference of

18 250 degrees. They just assumed.

19 And the best we can figure, after numerous

20 discussions and e-mail and conversation, is that they wanted

21 to conservatively estimate deposition due to possible

22 thermophoretic effects.

23 I guess it's also true that the entrance

24 temperature to the tube bundle isn't readily apparent from

25 the SCDAP output. We don't have that intermediate volume,

1 so, you know, if you're looking at SCDAP output, you've got
2 a choice of these things.
3 Well, we don't give you -- the output doesn't
4 automatically include that mix that's then also compensated
5 for by the mixing fraction and the ratio of the flows.
6 So, using a higher temperature, using a
7 temperature that's 15 times higher than ours produces more
8 thermophoresis. But, frankly, we just can't see any way
9 whatsoever you could get that kind of temperature difference
10 between the vapor and the tubes where the secondary side is
11 depressurized and there's no water.
12 Now, the people running the experimental facility
13 in Europe, the ARTIST facility, they're contemplating
14 looking at large thermophoretic deposition rates, but that
15 might be associated with putting some water back in the
16 steam generator where you can create large temperature
17 differences, in which case you could get that.
18 But the other issue -- you know, the obvious is,
19 if we the temperature that much hotter going into our tubes,
20 will it fail because the steam's too hot? I don't care what
21 the thermophoresis is.
22 The other point is if you think this is an
23 entrance effect, then it is in the tube sheet and I don't
24 know, maybe I am going out on a limb here but I guess that's
25 the last region I would worry about a lot due to fission

1 product heating anyway.

2 There the dominant mechanism was gravitational
3 settling at the top because it is a long distance and
4 actually Jason reminded me that it is liquid through much of
5 the system, so if you did deposit a little bit at the tube
6 sheet, it might be liquid. It might drip off and go down
7 into the inlet plenum and be on the bottom of the steam
8 generator.

9 Conclusions -- we have analyzed tube heating
10 during severe accidents using benchmark models validated
11 against scaled experimental data. It's undergone peer
12 reviews. Sensitivities have been examined. We have seen
13 temperature variations between 20 and 50 degrees.

14 We have evaluated tube performance during severe
15 accidents. We think that further evaluation though would
16 benefit from the resolution of thermal hydraulic
17 uncertainties. We have plants to undertake that work. We
18 think that a more rigorous consideration of uncertainties is
19 warranted. We think there's something to be gained by
20 looking at additional sequences for different plants and we
21 think there is a role for more detailed CFD modeling in this
22 calculation of details related to the mixing issue.

23 I do have a couple of viewgraphs on offsite
24 release. You had it in your agenda. It wasn't really a
25 part of a lot of our work. I didn't know if you were

1 interested in seeing anything about that or not. It is
2 basically the Victoria calculations that were done assuming
3 a tube rupture about the time of -- we simply ignored surge
4 line hotleg ruptures and modeled the tube rupture and we
5 continued the calculation until we predicted the hotleg
6 would have melted, okay?
7 DR. KRESS: Did you include the secondary building
8 and --
9 MR. TINKLER: Not the building.
10 DR. KRESS: Not the building?
11 MR. TINKLER: We did include the secondary side of
12 the steam generator.
13 DR. KRESS: Secondary side of the generator
14 itself?
15 MR. TINKLER: Of the generator itself, but not
16 additional deposition in the --
17 DR. KRESS: Once it got out of the secondary
18 side --
19 MR. TINKLER: It was out. It was out.
20 DR. KRESS: And you looked at both the control
21 room and --
22 MR. TINKLER: No. No, we were just looking at
23 fractions released.
24 DR. KRESS: Oh, fractions released.
25 MR. TINKLER: Fractions released, yes. These are

1 fractions of core inventory released.

2 The reason we didn't have more noble gases

3 released is because we released them through the PORV.

4 DR. KRESS: Okay.

5 MR. TINKLER: But we had about a 30 percent iodine

6 release -- so -- that's a real iodine spike.

7 DR. KRESS: How come the cesium gets to be so low

8 in this? Let me see it again.

9 MR. TINKLER: Yes. Cesium released from the core

10 is only 35.

11 DR. KRESS: I have always wondered about that.

12 MR. BALLINGER: Cesium is highly soluble, right?

13 MR. TINKLER: Yes. It's going to be cesium, most

14 of it in this calculation would be cesium hydroxide.

15 DR. KRESS: You know, a lot more of it got

16 retained in the primary-secondary than the iodine. That's

17 what -- that one is one that bothers me, I guess.

18 MR. CHAPAROW: This is Jason Chaparow from the

19 Office of Nuclear Regulatory Research.

20 The releases from the core, as you can see, are

21 limited to about three-fifths of the core, if you look at

22 the nobel gases and the iodine and the cesium is not far

23 behind it.

24 In this sequence we had, after the tube rupture we

25 continued to get accumulator injections and that kept the

1 lower part of the core down below about 1500 K so the lower
2 two-fifths we really didn't predict much fission product
3 release until this hotleg melted and you just -- the rest of
4 the steam boiled off so the lower area of the core was
5 predicted to be a little bit cooler, cool enough to prevent
6 the fission product releases prior to hotleg melting.
7 That affects all of the releases to the
8 environment by almost, by 40 percent.
9 MR. TINKLER: We heat the whole system up by
10 continuing this calculation. We just get revaporization of
11 iodine and it goes out --
12 DR. KRESS: Okay.
13 MR. TINKLER: -- and we did a brief comparison
14 against the early, early MAAP calculations on this thing.
15 For some reasons their release wasn't through the
16 PORV so they had more of it go out but on the iodine release
17 it is about the same.
18 DR. KRESS: But it is a large release?
19 MR. TINKLER: We consider that a significant
20 release.
21 Four hours though may be judged to be --
22 DR. KRESS: May not be a large early release.
23 MR. TINKLER: May not be early. Actually the
24 calculations typically produce, typically would involve some
25 evaluations, so there's not much going on prompt.

1 DR. KRESS: So it may not be kosher to equate this
2 directly with the large early --
3 MR. TINKLER: No, not if you are talking about
4 four to nine hours, four to eight hours, something like
5 that, maybe not. Well --
6 MR. HOLAHAN: Well --
7 MR. TINKLER: Well --
8 MR. HOLAHAN: Well, it's sure not small.
9 MR. TINKLER: My comment was how early was early?
10 This surely was -- I didn't say large. We said significant,
11 but it is, the difference between significant and large in
12 this case may be small.
13 [Laughter.]
14 MR. HOLAHAN: I think there was a comment earlier,
15 maybe Steve Long made it, and that is when you have the
16 choice between treating cases like this as large early
17 release or as core damage with basically no release, they
18 look more like the large early releases.
19 DR. KRESS: It would be prudent to do that.
20 MR. HOLAHAN: It would be prudent to do, yes.
21 [Pause.]
22 MR. LONG: I wanted to clean up a couple of
23 things.
24 First of all, I made a comment when I was up here
25 earlier about the amount of radioactive material that would

1 go out from the hundred GPM size hole and the tubes if you
2 went through the station blackout core damage accident
3 sequence to the point where you failed the surge line, and
4 then went ahead and failed the surge line in the
5 containment.
6 I tried to grab the document during a break and
7 grabbed the wrong document so I think we need to owe you
8 that document. My memory is probably not good and Charlie's
9 memory is better about how much of the radioactive material
10 went out from that particular case and how it would compare
11 to a contained reactor accident.
12 I think my memory is probably good that it wasn't
13 approaching LERF but in terms of the multiples of the
14 contained reactor accident releases were probably not on
15 target.
16 Another thing I would like to do is there was a
17 question about whether or not the tubes having flaws in them
18 made a difference when they would fail. I wasn't sure if
19 that was a question about if the tubes were 9505 tubes
20 confined in the support plates or if they were free span
21 flaws, so if they are free span flaws it will definitely
22 make a difference and it depends on what is going on in the
23 RCS in terms of heatup and pressure changes.
24 This isn't probably the best slide that I should
25 have. It is just a slide that I happen to have. What we

1 did is we modified RELAP/SCDAP to take account of tube
2 temperatures with different stress multipliers so it
3 simulated tubes with different size flaws instead of looking
4 just at the pristine tube.
5 I think you can kind of read it from your chairs
6 but the black is the weakest tube and it is something that
7 is just about I would say main steam line strength or so and
8 the 1X is essentially a pristine tube, so you can see the
9 pristine tube is going to fail last and this is a
10 sequence -- I'm sorry I don't have the other slides to show
11 you the temperature and pressure differences but what is
12 happening in this case is this is one of the intermediate
13 pressure cases and you have some repressurizations, the
14 depressurizations, and there is a question about what
15 happens when you have pressure pulses also.
16 What happens on the first pressure pulse is that
17 you force the hot gas up into the tubes and then because
18 there is not much on the outside of the tubes in a
19 depressurized generator they don't cool off very quickly and
20 then what happens in the next pressure pulse is that they
21 are already hot and you start accumulating creep damage, so
22 you start seeing this stepwise behavior.
23 It gets quite complicated, especially when you
24 look at this variety of different strength tubes because of
25 different flaw sizes.

1 Now if we start talking about the 9505 case,
2 typically in the flaw distributions we see, whether they are
3 9505 flaws or they are free span flaws, you see a few that
4 contribute the bulk of the leakage, whether they are the
5 measured flaws in the generator that it might pop at main
6 steam line break or they are the projections through MONTE
7 CARLO.
8 It is not typically a large number of flaws that
9 would contribute just a little bit of leakage in the free
10 span that gives you the big total. It is the handful of
11 flaws that are contributing most of it.
12 If you start doing that realistically where they
13 are confined in the tube support plates and maybe squeezed
14 shut and you are heating everything up it is not clear to me
15 that those cracks will even open under those conditions, but
16 if they do we don't expect -- the main point here is we are
17 not expecting a 132 GPM leak value to occur.
18 We are thinking it is going to be closer to the
19 one that we know we are permitting. Originally when we were
20 doing these we were talking about not one but six and we
21 were pretty confident that something that would leak six in
22 the free span that was encased in tightly-clenched crud
23 would probably not leak one.
24 As the number went from six to 20 to 50 to 132, we
25 thought we needed to start asking the question again about

1 how much it leaked through the crud.

2 CHAIRMAN POWERS: When we talk about the cracks

3 contained within the top and bottom planes of a tube support

4 plate, I think yesterday when we discussed those cracks we

5 said that indeed there were opportunities for those cracks

6 to extend above those two planes?

7 MR. LONG: We don't allow that. The question is

8 can we always detect it, can they grow during the cycle, the

9 intent is to not have them do that, and, somebody correct me

10 if I am wrong here, but I think it's sort of immediately

11 reportable if it's detected to have occurred.

12 MR. STROSNIDER: This is Jack Strosnider.

13 I think what Ken Karwoski was referring to was

14 there's been some metallurgical studies of pulled tubes

15 which showed that the cracks extended slightly above the

16 tube sheet and I think he was pointing out that there may

17 have been some crud sitting on top of some of those tube

18 sheets, providing that environment.

19 There is a requirement for licensees that adopt

20 95-5 to inform the Staff if they detect flaws extending

21 outside the support plate.

22 Now clearly their ability to do that is driven by

23 the certainty or the confidence you have in the inspection

24 but typically the length sizing is somewhat better and also

25 it's my understanding when you look at the eddy current

1 trace you can see the edges of the support plate so you have
2 got some reference point there to work with so -- but at
3 least in terms of any significant crack extension beyond the
4 edges of the support plate I think we have got controls in
5 place so that we don't have worry should it happen.
6 MR. LONG: I think the next step is human error
7 probabilities and it's Gareth Parry.
8 CHAIRMAN POWERS: Am I correct, Gareth, that you
9 have flow in special for this extraordinary opportunity?
10 MR. HOLAHAN: Let me confess to having dragged him
11 in.
12 [Laughter.]
13 CHAIRMAN POWERS: I happen to know that he looks
14 forward to every one of these opportunities. He probably
15 will send you a note of thanks.
16 MR. HOLAHAN: Having dragged him in, let me soften
17 up some of the blows to the point of Gareth didn't do many
18 of the analyses that he is going to talk about and I think
19 he might not have done any of the analyses that we have
20 talked about in the last two days.
21 The people who did those analyses are either not
22 available or they don't work at those places that they
23 worked when they did the analysis for the Staff. Some of
24 the things that he is going to present to you were sort of
25 patched together from information that are in a number of

1 reports, so if the questioning gets too hard I will try to
2 protect him a little bit.
3 CHAIRMAN POWERS: Well, understand that one of the
4 things that we very much want to be able to respond to is
5 the contention that the human error probability is taken to
6 be 10 to the minus 3rd and we need to understand how that
7 number came about.
8 MR. HOLAHAN: I understand and I have to confess
9 that as an amateur PRA practitioner I did some of the human
10 reliability analysis on one of the earliest reports.
11 CHAIRMAN POWERS: Let's see. If we go through the
12 SME qualifications --
13 MR. HOLAHAN: Not even close.
14 [Laughter.]
15 MR. PARRY: With that I will basically just even
16 strengthen what Gary said and say that what I am really
17 going to talk about is very general stuff since in fact I
18 think the questions you had -- that accompanied the agenda
19 were fairly general, and if it is not what you want to hear,
20 please stop me and I will be happy not to tell you.
21 CHAIRMAN POWERS: One of the things that I very
22 much want to understand is this 10 to the minus 3rd human
23 error probability that was quoted by the DPO author.
24 MR. PARRY: That is not something that I can
25 comment on -- but what I will do I think is just tell you

1 the process that as an HRA practitioner you would go through
2 and then maybe somebody could help you to see whether in
3 fact in the analyses that such a process was in fact gone
4 through.
5 CHAIRMAN POWERS: Can you give me some context to
6 put to the 10 to the minus 3rd, what kinds of human
7 activities have probabilities for human error of 10 to the
8 minus 3rd? Nothing I do, I know that --
9 [Laughter.]
10 CHAIRMAN POWERS: I hope. Point one is on the
11 best day I've ever had --
12 MR. PARRY: So you crash your car every one in 10
13 times you are supposed to brake? I don't think so.
14 CHAIRMAN POWERS: Good recovery.
15 DR. BONACA: The 10 to the minus 3 was associated
16 with the failure of the operator to depressurize and cool
17 down, that step.
18 MR. PARRY: For what?
19 DR. BONACA: For a steam generator -- essentially
20 for a rapid cooldown caused by a steam line break on the
21 secondary side followed by difference size ruptures, okay,
22 in the steam generator tubes ranging between 100 to 1000 GPM
23 so a fraction of the tube to about two tubes.
24 I guess, just to give some background on that, it
25 seems as if looking at the scenario you have some indication

1 at some point in time that you have both a blowdown and
2 depressurization event and also some leakage to the
3 secondary side.
4 The time involved here in this scenario is hours
5 really.
6 DR. SIEBER: Maybe you should use two hours. The
7 whole event is --
8 DR. BONACA: No, no, that would be four, bigger
9 breaks. You know, this is only up to about 1,000 GPM.
10 DR. SIEBER: And the whole thing would be
11 accompanied by a lot of noise and shrapnel preventing verbal
12 communication.
13 DR. BONACA: But you have the destruction
14 procedures.
15 DR. SIEBER: Right.
16 DR. BONACA: The ERGs, which also include these
17 kind of scenarios.
18 DR. SIEBER: Right. And I guess that -- on the
19 basis of those sort of conditions, if you can convince
20 yourself that the scenarios, in fact, -- if the procedures,
21 in fact, do help you through those scenarios to the correct
22 actions, and the cues are fairly obvious and not confusing,
23 then if you have that much time to react, and, presumably,
24 it doesn't take that long from the depressurization, I
25 wouldn't have thought that 10 to the minus 3 was an

1 unreasonable number.

2 You do find in PRAs human error probabilities even
3 as low as 10 to the minus 5 for very protected time scales
4 and for things that are obvious like initiation of
5 suppression pool cooling in a BWR. I think where you tend
6 to have high error probabilities is where the conditions are
7 such that the cues are not obvious, or the procedures are
8 not helpful, or there just isn't much time.

9 So I would have thought that 10 to the minus 3 was
10 not necessarily a bad number.

11 MR. HOLAHAN: Can I go back historically? Not
12 that I want you to take away the mid-1980s calculations as
13 our best current thinking, but I think they do address one
14 important aspect, and that is that quoting 10 to the minus 3
15 is misleading. The analysis done in the 1980s, and the
16 stuff done by INEL and by the staff in the 1990s, and you
17 heard about some of the thermal-hydraulic analysis earlier,
18 those analyses are very similar from the point of view of
19 the thermal-hydraulic and the systems analysis, and the
20 amount of time available and what needed to be done.

21 In fact, in the 1980s, a value of 10 to the minus
22 3 was also used, but it was used for what I would describe
23 as the simplest cases, and those were the cases of a single
24 tube rupture with either a main steamline break or some
25 other secondary side failure in which the times available

1 for operator action were in the range of 15 to 20 hours,
2 okay. And those are the cases that were ascribed to 10 to
3 the minus 3.
4 And looking at the multiple tube failures, in the
5 range of two to 10 tube failures, times tended to be on the
6 order of about five hours, and those were given a 10 to the
7 minus 2 on reliability. And cases of 10 and more tube
8 ruptures, in which case the operator had actions to take
9 more or less on the scale of one hour, were given .5 failure
10 probability. So when you hear the number quoted, it is not
11 for the most extreme multiple tube rupture with a big
12 steamline break, but it is complicated.
13 DR. POWERS: Let me ask a couple of questions. We
14 have got our expert here. Maybe we deviate a little bit
15 from your planned presentation.
16 MR. HOLAHAN: That's fine.
17 DR. POWERS: I am looking for insight on these
18 numbers. One of the -- and maybe, Mario, you are the right
19 one to describe this a little better. At least when we look
20 at it, it seems to us that there are protracted times for
21 all small numbers of tubes up to maybe not 15, but certainly
22 10, that are hour times of timeframes.
23 We have more troubles with loud noises and
24 shrapnel and all kinds of things going on. But in thinking
25 about it, we said, gee, the cues available to the operator

1 to understand what is going on are perhaps least at one
2 tube, and if he has a long time to respond, he can easily be
3 confused, but they become much more clear as we move up to a
4 few tubes. And then, as you move beyond that, you start
5 losing time. So that there might be an optimum in here of
6 tubes.
7 MR. HOLAHAN: I am convinced the optimum is zero.
8 DR. POWERS: You are looking at a grander, on a
9 larger scale optimization than I am. Now, is this
10 completely ridiculous thinking?
11 DR. BONACA: No, no. In fact, I think that the --
12 well, first of all, yeah, what Gary said is correct. I mean
13 this is in reference to NUREG-1477 where we pointed out it
14 is between a fraction of a small pinhole probably and range
15 all the way to maybe a tube, tube and a half, something like
16 that at. And if you look at the INEL analysis, they have
17 made different assumptions, because they have more tubes and
18 they go in 10 to the minus 2 and then .5. And so there is a
19 consideration of time.
20 Second, the INEL report makes the consideration
21 that when you go to beyond three to four tube ruptures, the
22 hole is large enough that you cannot repressurize.
23 Essentially, the pressure comes down on the primary side and
24 rather than coming back to the shutoff head of the high
25 pressure injection, tends to stay low, and there is clear

1 indication that there is a hole in the system. And so the
2 system itself drives itself to the conditions of
3 depressurizing and pulling down, I mean just simply it is
4 going there.
5 DR. POWERS: It is going itself.
6 DR. BONACA: And now again, even for those
7 scenarios, you have hours of time still to take some action
8 and, clearly, if you don't take action in two, three hours,
9 then you are going to go toward depletion of RWST. But the
10 procedures, if you look at the ERGs and you read them over,
11 there is a lot of consideration of that concern of RWST --
12 RWST depletion.
13 So they are not moot about that, they are talking
14 about the need of maintaining subcooling, but also to
15 prevent RWST depletion. And so you don't pump water for
16 hours and the operator simply is unaware that he is
17 depleting the RWST. In fact, he is going to be very
18 concerned about that.
19 And the other thing is that, which is encouraging
20 to me, is that the ERGs speak about the possibility of going
21 to RHR in a saturated mode, which means they are informing
22 the operator even during the training that he may not be
23 able to recover subcooling. But he then can -- which
24 implies that he has a large hole in the system. Okay.
25 So there are, you know, there is a lot of

1 information in the ERGs to be encouraging.

2 Now, the only thing that is confusing, and I want

3 to point out is that, if I remember, when you have a

4 steamline break, you have containment desolation, and you

5 have also -- I believe you have loss of the air ejector.

6 MR. HOLAHAN: Yes, that's correct. Yes.

7 DR. BONACA: Okay. So there is lack of some

8 indication there to make -- so that may delay at the

9 beginning his determination that he has a hole in the

10 system. But I don't think these numbers, I mean are that --

11 are reasonable. 10 to the minus 3, again, it is reasonable

12 in a scenario that lasts for 10 to 20 hours.

13 DR. POWERS: Well, my recollection is that we saw

14 a discussion. We had -- I mean it was a discussion I think

15 of perhaps the Halden reactor, where you had poor

16 performance despite these times and whatnot. I mean do we

17 understand why that is?

18 DR. BONACA: Well, first of all, I think -- I am

19 not sure the presentation really represented the situation

20 today where the ERGs are an established symptom oriented set

21 of procedures. I daresay that in the '80s, I would not have

22 the same level of confidence at all, because there was no

23 structured process to recognize, for example, this potential

24 for rapid cooldown and steam generator tube rupture. But

25 the ERGs recognize that very explicitly because they are

1 telling you how to get there.

2 And I don't know about the Halden project, if it

3 is recent, and I am not sure that the operators represented

4 there had, in fact, the helpful procedure structure the way

5 the ERGs are.

6 DR. SIEBER: I think there is another factor, too,

7 because you would end up in some kind of a callout status at

8 the plant, and you would have more help than you could shake

9 a stick at, including the technical --

10 DR. POWERS: That was universally recognized as a

11 bad thing.

12 [Laughter.]

13 DR. SIEBER: Well, nowadays it is supposed to be

14 organized and structured. And what you don't want is a lot

15 of people running in and out of the control room. On the

16 other hand, you have the ability to have turnovers. You

17 have the ability to do calculations. You have the ability

18 of innumerable people to critique and watch what is going on

19 and provide technical assistance.

20 The other thing that is not on that sequence is

21 there is a lot of other things that happen, because if your

22 power which causes the accident conditions, you get a

23 turbine trip or reactor trip, you have about 35 things that

24 you have to do to respond to that, and they are going to

25 open up safety valves, which make almost as much noise as a

1 break someplace in the steam system.

2 If it is inside the building, all your fire alarms

3 are going to go off, okay, like happened at Surry. And so

4 you are going to have enunciator lights and computers

5 reeling out tons of stuff on CRTs. And if that is

6 accompanied by a tube rupture, and you don't have in control

7 room N-16 monitor outputs, you are going to have a problem

8 recognizing that right away, because the reaction of the

9 parameters on the reactor coolant system which the operator

10 begins to monitor is the same for steamline break as it is

11 for a tube rupture for that first increment, until all of a

12 sudden, because you are going to go pretty far down on

13 pressurizer level and pressure is going to come down. The

14 plant is going to cool off pretty severely.

15 So it isn't until you are into that a little bit,

16 and you get that blowdown and the cooldown, you can tell

17 that, uh-oh, I am on a different path than what I would

18 expect.

19 DR. BONACA: That's right.

20 DR. SIEBER: With N-16 monitors, which are

21 required and aren't Reg. Guide 1.97, you can pick it up

22 pretty quick.

23 DR. BONACA: The last comment I would like to make

24 about that is that, you know, 10 to the minus 3 is always a

25 very hard number to -- you know, it is a very small number.

1 But the other comfort I got in reviewing this material is
2 that it comes out to an increasing CDF of 2 in 10 to the
3 minus 6, and I thought, what if it were 1 in 100, it will
4 come 2 in 10 to the minus 5.
5 So that gave me some comfort than even with
6 significant uncertainty applied to it, I would still get a
7 relatively small increase in CDF.
8 MR. BALLINGER: I need to get something squared
9 away in my mind. In the case of IP-2, the staff assigned a
10 probability of failure of .1 for that event, and I see 10 to
11 the minus 3 here. Operator failure.
12 MR. HOLAHAN: Failure to do what?
13 MR. BALLINGER: Failure -- now, that is what I
14 want to get square away? I mean Jack's -- well, it was
15 here.
16 MR. HIGGINS: I think it is important to realize
17 that we are talking about many different sequences here,
18 Ron, with all the different things, because over the last
19 two days we have talked about -- I mean we have gone through
20 the spontaneous steam generator tube rupture. We have gone
21 through the various accident induced ones that delta P
22 inducted. And all of those have somewhat different operator
23 actions associated with them considering the timing and
24 considering the actions and the stresses that John was just
25 describing, and those are all going to have different HEPs

1 when you do the calculations. So it is very much too
2 simplified to just say that 10 to the minus 3 is the number
3 used in these analyses.
4 DR. SIEBER: Another factor is that Reg. Guide
5 1477, I guess it is.
6 DR. POWERS: NUREG.
7 DR. SIEBER: NUREG. Really looks at the accident
8 as -- since the Reg. Guide 95-05, assumes that the tubes
9 don't rupture and just leak. It follows the simple event
10 tree of a steamline break, which is much simpler than having
11 these two events going on at the same time. And so the
12 analysis in 1477 may be justified because the accident, the
13 event tree that you are analyzing is simpler than one that
14 has these two accidents going on.
15 Actually, the question is, does the steam
16 generator hold up? And if it doesn't, it leads you into
17 another sequence which hasn't been analyzed here.
18 MR. LONG: What is 1477 was intended to look at
19 the DPO issue of a large amount of leakage due to cracking
20 that was in the freespan. So if you look at the event tree,
21 there is no conditional probability that leakage will occur.
22 That was just put in as one.
23 DR. BONACA: As one, yeah.
24 MR. LONG: And so it didn't really appear in the
25 tree. And then the intent was to try to deal with the

1 combined event. And, initially, we simply lifted the human
2 error probabilities from NUREG-0844 that Gary was talking
3 about earlier, and we went through some analyses to try to
4 figure out where we would leave them to be, with some
5 additional effort that I described yesterday, to some
6 degree, at least up to the point of what the inputs where.
7 And eventually, I believe, in 1570 we used 10 to
8 the minus 2 instead of 10 to the minus 3. So we did shift,
9 but we were still dealing with moderate primary to secondary
10 flows, not, you know, tens of thousands of GPM, but maybe a
11 thousand GPM or multiple hundreds of GPM for those events.
12 MR. PARRY: I think, though, the key really is for
13 them to be able to understand the status of the plant as it
14 -- particularly with the failure of both the secondary and
15 the primary side and whether the procedures will lead them
16 down that path.
17 I think initially, the -- I only know the
18 Westinghouse system, and that's from a few years back. I
19 guess initially there would be an E2, which would be the
20 steam line break from the generator and then maybe
21 transmission into E3 or even E1. And eventually, they would
22 end up probably doing the right things.
23 MR. BONACA: Yes. I mean, I didn't see anything
24 --
25 MR. PARRY: They all lead down the same path.

1 MR. BONACA: Yes. It will lead down the same
2 path. I believe tougher is going to be a small leak because
3 you have a steam line break, you don't know that you have a
4 small leak. But you have plenty of time to --
5 MR. PARRY: Right. To compensate for that.
6 Actually, in a sense, you cut straight to my last viewgraph
7 with your talk, so I'm really not sure it's worth going
8 through what I've written here because I think we have
9 covered the issues that -- yes, there's a possibility that
10 there is a confusion factor, and that's something that has
11 to be taken into account. The more confusing it is, the
12 less likely the likelihood they will succeed.
13 MR. HOLAHAN: I think there has been some
14 misunderstanding in the past on this point, a
15 misunderstanding that the staff had intended to use the
16 human error probability of ten to the minus three for some
17 extreme multiple tube rupture cases, and that has never been
18 done. So I think it seems to me that the real issue is not
19 how the operators would respond. No one is going to give
20 them credit for handling 100 tube ruptures with a main steam
21 line break. The real question is how likely is such a thing
22 to happen? Are there real mechanisms that would allow such
23 a thing to be sufficiently likely that they need to be
24 modelled.
25 MR. BONACA: The other thing that I think is

1 confusing somewhat is that the objective has always been one
2 of, you know, not emptying the ARWST. But as Dr. Ward
3 pointed out this morning, then there are hours before you go
4 to core uncovery, about four hours, and so it seems to be
5 very unlikely to think of an event of this kind evolving to
6 the point where you're emptying the ARWST and then you sit
7 there for four hours without doing anything. I mean, I
8 think in this comprehensive scenario, there are many
9 opportunities to take action and --
10 MR. PARRY: Yes. I mean, isn't there the
11 contingency to refill the RWST called out in the procedures
12 as well if you don't have anything in the sumps.
13 MR. BONACA: That's right.
14 MR. PARRY: Those are things you can do, and
15 that's probably not taken into account in these analyses is
16 my guess.
17 MR. BONACA: That's right, as well as, for
18 example, connections already existing with other tanks on
19 the site.
20 MR. PARRY: Right.
21 MR. BONACA: Many sites have additional RWSTs
22 available for make-up.
23 MR. HOLAHAN: Since I've already confessed to be
24 being a amateur HRA analyst, I would like to add three
25 thoughts.

1 The issue about operating experience showing that
2 operators didn't handle the events very well I think all
3 relates to the design basis issue of quickly isolating the
4 generators in the time frame of 30 minutes, and I think
5 those are valid criticisms, that the traditional use of 30
6 minutes is, in fact, not so easy for operators to figure out
7 which generator has the leak and basically to isolate that
8 generator in 30 minutes, because, in fact, operators,
9 although they figure these things out, the real process of
10 acting is more deliberate than the analysts assumed 30 years
11 ago.
12 Second insight is, at least from the NRC's end of
13 the phone calls, I've seen a number of events and many, many
14 drills, and there's a great deal of sensitivity to radiation
15 anywhere outside the reactor coolant system, and I think one
16 of the things we're talking about is, you know, an operator
17 having knowledge that there is a steam line break and a tube
18 rupture and radiation signals from around the plant I think
19 would, especially over the time frame of hours, would be
20 something the utility would be very sensitive.
21 Thirdly, the NRC operations center two floors up,
22 if we're talking about 15- and 20-hour scenarios and going
23 to core melt, I would have to think that we would have
24 failed on our end in figuring out what in the world was
25 going on in those plants, and as the director of the reactor

1 safety team in the operations center, I have a hard time
2 saying that we wouldn't figure it out on our end.
3 MR. BONACA: I would like just to add that I agree
4 the 30 minutes objective right now is one that seems to me
5 that is somewhat -- the operators almost because it's a
6 requirement that has to be met. But if there are some
7 complications there, they may not pay attention to those
8 because they're so focused on equalizing pressures between
9 primary and isolated steam generators within 30 minutes,
10 which is very challenging for them to do.
11 CHAIRMAN POWERS: Is it your perception that this
12 evaluation that was done for the Halton staff -- when it
13 says poor, is poor relative to a 30-minute time window which
14 seems to be a completely arbitrary sort of thing?
15 MR. HOLAHAN: It's not arbitrary; it's part of the
16 design basis dose calculation that Jack Hays showed you
17 yesterday as leading a small fraction of the part 100. But
18 from a severe accident point of view, it's irrelevant.
19 CHAIRMAN POWERS: Okay. Well, I guess I'm looking
20 at a design basis accident point of view right now.
21 MR. HOLAHAN: What I would say is from a design
22 basis point of view, the steam generator tube rupture and
23 dose calculations have many, many conservatisms. We once
24 calculated about four orders of magnitude of conservatisms
25 in the dose calculations, okay? And I think we talked about

1 iodine spiking and looking for the 95th percentile and the
2 meteorology 95th percentile.
3 Well, the one thing in that sequence that's not
4 very conservative is the time to isolate the generator,
5 because I think 30 minutes is certainly possible, you know,
6 but experience shows that 45 minutes or an hour is more
7 likely to see what happens.
8 But I think if you see that in the context of the
9 overall conservatism of the design basis calculations, it
10 doesn't bother me very much.
11 CHAIRMAN POWERS: Design basis are always very
12 confusing to me. I mean, there seem to be times when we're
13 lenient and times when we're not, times when we invoke risk
14 and times when we don't. Clearly in the design basis
15 analysis, by the time the day is over, we have no idea what
16 the total level of conservatism that you compose because it
17 shows up in multiple places. But you also have the same
18 problem when you start granting leniency, that it doesn't
19 bother you very much on these things. You don't know how
20 much of the margin you have taken away.
21 MR. HOLAHAN: But in this case, it doesn't even
22 bother me very much with respect to meeting the part 100
23 dose guidelines.
24 I understand it's a little different when you say
25 we're going to shave design basis margin because I don't

1 think the risk implications are very important. In this
2 case, I think the exact time of steam generator isolation
3 isn't really all that critical to meeting part 100
4 guidelines.
5 CHAIRMAN POWERS: I think I understand.
6 Do you have other points that you --
7 MR. PARRY: Not really.
8 [Laughter.]
9 MR. HOLAHAN: I would just like to summarize on
10 one point. The numbers I read you and that Steve said had
11 been picked up are at least 15 years old, that when we redid
12 some of the analysis in the 1990s, we rightly thought that
13 they should be re-looked at, and INEL did some human
14 cognitive reliability analysis and came up with some
15 approach.
16 But even when they did those analyses, they
17 identified them as screening type analysis and they thought
18 that some additional work ought to be done to, you know,
19 refine the answers.
20 So I think we're not saying that we know or have
21 really solid information on human reliability. I agree
22 completely with Dr. Bonaca's observation that you can do
23 some sensitivity studies and change the answers and see that
24 it's not all that critical if the values aren't quite ten to
25 the minus three, and they're certainly not ten to the minus

1 three, nor have they been claimed to be ten to the minus
2 three for the most severe cases that we've talked about.
3 CHAIRMAN POWERS: Gareth, I think I want to ask
4 you a question. It's going to be very difficult for me to
5 put forward. It's not a question you're going to want to
6 answer.
7 MR. PARRY: Then I won't.
8 CHAIRMAN POWERS: I'm going to plead passionately.
9 We have this design basis time window of 30
10 minutes in which we would like the operator to identify the
11 leaking steam generator and isolate it. We are told by Mr.
12 Holohan that this is a challenge for them, that in fact a
13 better time period for doing that isolation process might be
14 45 minutes to an hour. Jack has described to you a chaotic
15 situation in which there are lots of alarms going off and
16 whatnot. At the same time, we do have a pretty good set of
17 procedures.
18 From your vast storehouse of experience and
19 knowledge on these subjects, what would you guess the
20 probability that the -- I don't want to call it an error
21 probability -- the probability that an operator would fail
22 to complete this task within the 30-minute time frame?
23 MR. PARRY: You're right, I wouldn't want to
24 answer that question.
25 CHAIRMAN POWERS: But I'm going to plead so

1 pathetically.

2 MR. PARRY: And the reason I wouldn't, I think, is
3 because it's so dependent on the details of the procedure
4 and the training.

5 But let me give you one little insight, that if we
6 were analyzing -- typically if you're analyzing spontaneous
7 tube ruptures and you are concerned about the isolation of
8 the generator, the success criteria in most PRAs as I
9 understand it, or certainly the ones we used to use, were
10 not 30 minutes, it was before the steam generator
11 over-filled, which typically would be on the order of an
12 hour depending on the size of the leak.

13 So -- and for those -- for that particular step in
14 the procedure, and just the isolation, I think -- I'm trying
15 to think back. Typically we would probably have used an
16 error probability of the order of ten to the minus two. But
17 at that point, then it becomes a contained accident. And
18 the worst case is if they don't do in that time, then we
19 have to go down to RHR.

20 So those scenarios, I think the error probability
21 for that simple single tube rupture type scenario I'm pretty
22 sure was a lot less than ten to the minus three because of
23 the length of time available.

24 MR. HOLAHAN: Could I add something? I just
25 wanted to add something to that.

1 Before I came, I went through -- we were doing
2 some work for the STP process for the NRC as far as
3 developing the risk-informed inspection notebooks and
4 developing the operator actions and the credit for those in
5 those, and I went through and looked at some of the steam
6 generator tube rupture related human actions from IPEs and
7 for the PWRs, there were two that were important. One was
8 this early isolation of the ruptured steam generator and the
9 other one was depressurizing the primary, and they both
10 typically run around ten to the minus two. I've got some
11 data here from -- I don't know -- maybe 30 plants, not all
12 of which have clearly identified HEPs that you can extract,
13 as Gareth knows. But I would say in general, they average
14 about between 1.0 and 2.0 times three to the minus two for
15 each of those actions separately.
16 MR. PARRY: Now, what you said about
17 depressurizing the primary, you're talking about
18 depressurizing to RHR entry conditions. Is that --
19 MR. HOLAHAN: Right. Depressurizing it below that
20 of the secondary, not all the way to RHR.
21 MR. PARRY: Okay. Okay. Just to stop the leak.
22 MR. HOLAHAN: Right.
23 MR. PARRY: Okay.
24 MR. HOLAHAN: Right.
25 MR. PARRY: Okay.

1 CHAIRMAN POWERS: One of our speakers earlier in
2 the week presented a -- I guess his assessment of the
3 performance of various operational teams during the course
4 of a spontaneous steam generator rupture event, and I was
5 trying to find it, but my recollection is that it's a litany
6 of delay doing this task, doing the other task, delay doing
7 the third. Is that coached, these numbers, that you get ten
8 to the minus two human error probability? I mean, it's
9 funny because, I mean, it's a time window. The guy can do
10 it successfully in 35 minutes. Do I count that as a failure
11 because it wasn't 30? I mean, it doesn't seem right to do
12 that.
13 MR. HOLAHAN: Not in PRA space, you wouldn't.
14 CHAIRMAN POWERS: Not in PRA space, but we're in
15 design basis space.
16 MR. PARRY: No, we're in PRA space.
17 MR. HOLAHAN: Yes.
18 MR. BONACA: I can't remember exactly. You
19 remember the time frame for those tests?
20 CHAIRMAN POWERS: They weren't tests.
21 MR. PARRY: Yes, they were --
22 CHAIRMAN POWERS: These were events and they
23 extend from the early '70s up until just a few months ago.
24 They span quite a range.
25 MR. BONACA: Yes. First of all, I would separate

1 time. I think that after --

2 CHAIRMAN POWERS: Well, the story was consistently

3 the same. It was always delay doing something, and my

4 recollection of IP2 was there was a pretty good story there,

5 too.

6 MR. PARRY: Did any of those events lead to

7 over-filling the generator?

8 CHAIRMAN POWERS: I believe there was one of them

9 at least that did lead to over-fill of the generator.

10 MR. PARRY: That one I would count as a failure

11 for the isolation.

12 MR. HOLAHAN: I would consider it a design basis

13 failure. Among other things you would have released water

14 as opposed to steam and so partitioning and a lot of other

15 things in the analysis don't come out right.

16 CHAIRMAN POWERS: You would jump all over Ginna?

17 MR. HOLAHAN: I believe I did.

18 [Laughter.]

19 MR. LONG: I think part of the point here is that

20 Jim has talked about the human errors for our failing to

21 isolate when the -- well, in your case I guess it was the

22 overfilling, it was the IPEs.

23 That is not the whole step to core damage though.

24 If you look at the way the rest of the logic goes, there's

25 typically another human action in there or some other

1 equipment failures that you have to use to get the core
2 damage so if you take the product of the human errors, that
3 gets you all the way to core damage in that particular cut
4 set that is just pretty much all of the operator's fault.
5 The number typically comes out more like 10 to the
6 minus 4 as the total product, maybe lower depending on the
7 PRA.
8 MR. PARRY: That's right.
9 MR. LONG: That was the kind of number we were
10 trying to capture when we did the event trees for 1477 and
11 the sort of event lists for 0844. It was the total process
12 so that top event was operator fails to pressurize, cool
13 down RHR.
14 In that regard I think we are being somewhat more
15 conservative than what you would see for the spontaneous
16 rupture for the overall human error.
17 DR. SIEBER: I guess what I am struggling with, I
18 have got 10 to the minus 3. I have a historical inventory
19 of events that I will admit goes from the Dark Ages to the
20 Modern Day.
21 MR. HOLAHAN: Zero for 10 core melts.
22 CHAIRMAN POWERS: But one that excited the
23 esteemed Holahan and got him agitated and he considered a
24 failure.
25 MR. PARRY: No, a failure to isolate the

1 generator.

2 CHAIRMAN POWERS: Now he considered it a failure.

3 MR. LONG: It was a failure to prevent overfill, I

4 think was the issue.

5 CHAIRMAN POWERS: I think it was a failure to

6 prevent release of radioactivity to the outside.

7 MR. HOLAHAN: That is before I became an amateur

8 PRA expert.

9 [Laughter.]

10 CHAIRMAN POWERS: It is not entirely clear that

11 that is a step forward on the evolutionary path.

12 DR. BONACA: Let me just say a couple of things I

13 would like to say about that.

14 First of all, again as I said yesterday, steam

15 generator tube rupture within the constraints of what they

16 are supposed to with the objectives, the 30 minutes, some of

17 the most challenging sequences, because the time is short.

18 Certainly they are not going to have any help very much.

19 That is control room delivery issues. Many of

20 them are dealing with other issues. For example, because of

21 spurious safety injection actuation many of them are running

22 with their block valves closed on PORVs on some of them, and

23 then that complicates the ability of depressurizing and all

24 this kind of stuff.

25 So the 30 minutes becomes a real difficult time,

1 okay? Now here when I was looking at these other scenarios,
2 which is very different -- you have a depressurization on
3 the primary side and you have a tube rupture in addition to
4 that, both of them are helping in the direction of going
5 towards a target which is the one of depressurizing and
6 cooling down within hours.
7 That is a different story because when it passes
8 30 minutes you are going to have, with an event like this
9 you are going to have all kinds of help coming down to the
10 control room. Now hopefully it is not all confusing, the
11 help, but people are going to begin to see things and there
12 are signals around the site telling things so even if there
13 was a guy who absolutely misunderstands the event, the
14 others will not.
15 I mean that is -- that was one consideration I had
16 in the sense of how confusing is it going to be, how
17 ambiguous is it going to be.
18 The other issue is -- again, I don't want to
19 minimize that -- I said to myself what if it was 1 in 10 to
20 the minus 2 and that still would get to a number of two 10
21 to the minus 5 for CDF so the contribution was still
22 acceptable with the significant error range that because
23 again I mean there is an uncertainty there --
24 CHAIRMAN POWERS: The truth of the matter is that
25 two times 10 to the minus 5th is not what I would call

1 inconsequential.

2 I mean that gets me interested at least in the

3 sequence.

4 MR. LONG: That was with guaranteed massive

5 leakage.

6 CHAIRMAN POWERS: I keep coming back -- I keep

7 coming back -- I know the consternation of most to the

8 design basis issue because I think that is the issue I have

9 to confront.

10 Suppose that I said that I will forgive the 30

11 minute window. I don't care. That's somebody else. What I

12 really, really want to do is I want to prevent the release

13 of enough radioactivity to get the younger Holahan prior to

14 his exposure to PRA excited about the radioactivity release.

15 Why would I not be justified in saying that the

16 failure to keep Holahan happy criterion is a .1 probability?

17 MR. LONG: Based on the empirical evidence?

18 CHAIRMAN POWERS: Yes, the empirical evidence yes.

19 DR. BONACA: For steam generator tube rupture?

20 CHAIRMAN POWERS: Yes, spontaneous steam generator

21 tube rupture. I have one that I know for sure got him

22 upset.

23 MR. HOLAHAN: Which didn't exceed Part 100.

24 CHAIRMAN POWERS: I understand. I understand --

25 still got you upset. I mean it got you interested.

1 MR. HOLAHAN: It's cold in --

2 CHAIRMAN POWERS: It's not terribly cold, it

3 snows.

4 DR. BONACA: I wouldn't disagree with that

5 estimate for the steam generator tube rupture.

6 MR. LONG: I think people have modified procedures

7 a lot since then so you might get back into Gareth's

8 expertise by trying to figure out what the new probability

9 is if you think it has changed. That is the issue.

10 CHAIRMAN POWERS: I think that's a very fair

11 statement.

12 MR. HIGGINS: Let's say it is and it may very well

13 be .1 to do the thing you just described.

14 Is that an issue? I don't think so.

15 MR. HOLAHAN: Not necessarily. As a matter of

16 fact my sympathies at the moment are with Dr. Bonaca.

17 I mean if we had to do it over again I would say

18 we have got to be more realistic in the overall calculation

19 of, you know, dose and consequences of steam generator tube

20 rupture and put less demand on the operator and a little

21 more demand on the meteorology and we may very well meet the

22 same goals in a more appropriate fashion.

23 MR. LONG: One thing -- I'm sorry, Gareth, go

24 ahead.

25 MR. PARRY: No, I wasn't going to say anything.

1 MR. LONG: One thing that we should mention before
2 we get off the subject is that the Office of Research has a
3 program and I think you have heard of that called Athena, to
4 look at errors of commission and omission and procedures,
5 and I think one of the things they are doing this week that
6 is making it hard to get the right people in the right place
7 at this time is to start looking at steam generator tube
8 rupture issues with that new process.
9 Also, I want to point out that Indian Point --
10 Consolidated Edison has proposed breaking the steam
11 generator tube ruptures, at least the spontaneous ruptures,
12 into two categories, sort of like small and large LOCAs or
13 small and large tube ruptures, the splits being kind of
14 plant-specific, the bottom of the small being that your
15 first charging pump has run out of capacity and you have to
16 do something to add charging and the top of the small being
17 you have no more charge to add -- you have to go to safety
18 injection and then the safety injection is the -- onward is
19 the larger sizes.
20 I think there's some benefit to that because I
21 think the human errors are probably different and the
22 opportunities for making it worse are still there while you
23 are in the lower leak rate --
24 CHAIRMAN POWERS: I think the opportunities to
25 make it worse is the advantage of doing that.

1 I mean I see it as an advantage.

2 MR. LONG: One of the other things -- we haven't
3 mentioned it yet -- but if you have the secondary side
4 failure first, one of the things the operators are worried
5 about is the cooldown rate, and there's a lot of competing
6 things in there -- keeping the core covered, keeping
7 subcooling margin, trying not to get your cooldown rate to
8 be too large, and they'll sometimes try to heat back up real
9 quick because it is over an hour the way they see it and
10 they are trying to put this all together with the Athena
11 program, so I think there is some opportunity for re-looking
12 at this and maybe coming out with more of a consensus on how
13 to do these things, because as I pointed out earlier, just
14 in the IPEs there were almost four orders of magnitude
15 difference in the result of the way people were applying the
16 logic to just the spontaneous rupture in the industry right
17 now.

18 That is not a very good, firm basis. My next
19 slide is on uncertainties and that certainly is one of them.

20 MR. HOLAHAN: I wanted to tie this issue back to
21 the design basis. I think you said you want to wrap that up
22 somehow.

23 It seems to me that there are a number of issues
24 here which could use a re-look by the Staff at how the
25 design basis steam generator tube rupture is treated.

1 Frankly, I wasn't completely happy with our
2 discussion of iodine spiking in that I think the story
3 wasn't entirely convincing, although I think the licensing
4 basis that we have used is reasonable but I don't think we
5 told the story in a convincing way.
6 I think there are a number of conservatisms in the
7 design basis steam generator tube rupture that are not
8 necessarily serving the public or licensees very well, which
9 in my mind makes it a good candidate for risk informed
10 re-look.
11 In that context I would say you could look at
12 realistic iodine spiking. You could look at the demands you
13 are putting on the operators and what makes sense and what
14 is counter-productive.
15 You could re-look at the conservatisms in
16 meteorology and other issues and I think today we could come
17 up with more sensible design basis requirements for steam
18 generator tube ruptures than we have inherited over the last
19 30 years.
20 CHAIRMAN POWERS: I am pretty sure I agree with
21 you.
22 [Laughter.]
23 MR. HOLAHAN: And if a committee were to recommend
24 that to me, all I would have to do is prioritize it with our
25 other risk-informed activities.

1 CHAIRMAN POWERS: I understand that the committee,
2 this committee, gathers facts and provides information to
3 the ACRS. The ACRS will in turn make a recommendation to
4 the EDO.
5 MR. HOLAHAN: I certainly wouldn't want to
6 influence that process.
7 [Laughter.]
8 CHAIRMAN POWERS: And let me assure you you
9 haven't.
10 MR. HOLAHAN: Thank you.
11 [Laughter.]
12 CHAIRMAN POWERS: I think I understand better my
13 design basis human nonconformance probability. I think we
14 have lots of fertile thinking on the severe accident side of
15 this.
16 I, myself, find very attractive this idea that
17 there are gradations in that error probability that are not
18 linear and with the magnitude of the break kind of
19 fascinating.
20 Is there anything else you need to tell us?
21 MR. PARRY: No, but if you are more interested in
22 human reliability there is a graduate course they give at
23 the University of Maryland --
24 DR. KRESS: Who is teaching that?
25 CHAIRMAN POWERS: Anyone I know?

1 MR. PARRY: Possibly.

2 CHAIRMAN POWERS: Could I get a good grade?

3 [Laughter.]

4 MR. PARRY: That depends.

5 MR. HOLAHAN: I can tell you, I am not willing to

6 take the test.

7 MR. LONG: I guess the next subject on there was

8 uncertainties in the risk assessments.

9 Shall we plunge ahead?

10 CHAIRMAN POWERS: Sure, please.

11 MR. LONG: I think we have talked about these to a

12 large degree. There are sort of three areas that I want to

13 talk about. The human error probabilities. I think I won't

14 spend any more time talking about the uncertainties in

15 those.

16 We have talked about the NDE detection of flaws,

17 and I think you have seen the POD in that. I will mention a

18 couple of things that came out of some reviews of license

19 applications.

20 Then there are the tube strength estimates based

21 on the NDE characterizations of the flaws.

22 When I wrote that slide, I think I left off

23 thermal-hydraulic modeling uncertainties.

24 MR. POWERS: I didn't think there were any. I

25 thought thermal-hydraulics was a well established field of

1 an exact science.

2 MR. CATTON: It's considered to be a mature

3 science, but not exact.

4 MR. POWERS: It's only the participants that are

5 mature.

6 [Laughter.]

7 MR. KRESS: Geriatric science.

8 MR. LONG: When we did NUREG-1570, we tried to do

9 sensitivity studies on the various things that went into the

10 risk assessment. What we really figured out was it looked

11 like we were very sensitive to what the flaws were. If you

12 took a different flaw distribution, you got a different

13 answer. We were very sensitive to what the temperatures

14 were on the tubes at least relative to the surge line in

15 terms of heatup rate of the tube in competition.

16 We were sensitive to whether you had cutting from

17 small flaws or not. In other words, the cutoff size of 0.25

18 and how much you worried about the small flaws. We knew

19 that, and we reported that in the report.

20 Then, as we went forward and tried to apply this

21 later on, we found some other things. In particular, with

22 the thermal-hydraulics the RELAP/SCDAP output is the

23 temperature of one assumed to be representative of the heat

24 transfer hot tube. I'm not sure exactly what that means in

25 terms of average over the tube sheet for the different tubes

1 that are carrying the flow, but when we do these
2 calculations we need to know what the hottest tube is. We
3 want to know if either the pristine tube or a tube has sort
4 of an undetectable expected amount of degradation in it
5 since the tubes are to some degree aged and there are some
6 things that are on the order of 20 percent through wall you
7 probably just can't find.
8 We don't really have that. There are varying
9 opinions as to how close we are to that with the RELAP
10 number. If I talk to some people, I hear, well, we're very
11 close. If I talk to others, there is some concern that we
12 are not very close at all.
13 So that is the beginning issue.
14 The next part of it is, if somebody tells me I
15 have a few flaws and they are distributed somewhere in the
16 hot leg side of the tube sheet, I don't know, first of all,
17 if they are in or not in the hot part of the bundle. If I
18 am told that the hot part of the bundle is 53 or 35 percent
19 of the bundle, at least I have a statistic I can start using
20 to try to get a probability that one of my bad flaws is
21 within that region.
22 But within that region there is quite a variation
23 in tube temperature. So I have difficulty in trying to
24 figure out what the probability is that my weak flaw is
25 going to my hottest tube or a tube that is at least hot

1 enough to cause it to fail before the surge line.

2 I tried in the Farley analysis about a year and a

3 quarter ago to squint real hard at the distributions of tube

4 temperatures like I showed you before and tried to get some

5 areas that I thought were hotter by a certain amount than

6 the temperature that RELAP predicts, and for that matter,

7 there has to be some that are cooler as well to make that

8 some sort of an average. I purposely didn't write down the

9 details because I didn't think I did well enough that I

10 wanted anybody to just copy it. In the NRC, if you are not

11 careful, it will just be copied by the licensees from then

12 on because it's something that they think we are going to

13 approve since we did it ourselves.

14 I noted that if I scaled the difference in the

15 tube sheet temperatures just from what I could see from

16 variation in the tube sheet, if I took the delta between the

17 cold and the hot as the scaling parameter and then looked at

18 the fraction of that delta, I get a different answer than if

19 I took the delta from the hot leg to the tube sheet and

20 looked at the variability.

21 So there is a real issue here about how do you get

22 a distribution of temperatures on the tube sheet.

23 MR. CATTON: I would agree with that.

24 MR. LONG: I knew you would, but I know some

25 others won't.

1 So it basically comes down from the mixing of the
2 countercurrent flows and what we can do with those.
3 MR. CATTON: This is the same exercise that I went
4 through a few years ago to the same conclusion.
5 MR. LONG: We have talked about some beginnings to
6 try to get more information on that. There is some question
7 about how far we can go without doing physical studies.
8 Right now NRR has asked Research and Research has responded,
9 and we have said, yes, that looks like a good start. The
10 question is, will we get to what we need to do these things
11 adequately for licensing purposes.
12 We have talked about the effects of leakage on the
13 tubes. We don't know where that really starts becoming
14 important.
15 We also talked about sort of the non-stylized
16 accidents where you have leaks of different sizes in
17 different places and the RCS and what effects that may have.
18 It really complicates the picture quite a bit.
19 We also have a concern that we seem to get
20 consistent differences between MAAP calculations and RELAP
21 calculations. Of course there are people who wrote one that
22 are throwing bricks in the direction of the guys that wrote
23 the other. Mark Kenton has been doing a fair amount of work
24 to try to figure out if he can make MAAP look the same as
25 RELAP. One of the things that he has picked up is he thinks

1 he sees an importance in radiative heat transfer between the
2 fluids and the walls.
3 MR. CATTON: What is the fluid?
4 MR. LONG: At the point he is doing it, it is high
5 pressure, high temperature steam.
6 There is also the differences that the licensees
7 are giving us calculations with one code; we are using
8 another code, and they don't tend to predict the same order
9 of stuff failing necessarily, much less the same timing or
10 the same temperatures.
11 So we feel there is a fair amount of uncertainty
12 here, and it makes it difficult to do an analysis and then
13 to take that into the decision making process.
14 I will go a little bit further than the slide was
15 intended to go and say, when I had to do this for Farley, I
16 sort of had an option of telling Farley that their
17 application really didn't address Reg Guide 1.174 or to
18 recognize that we really hadn't ever put out any guidance
19 although we had been asked for it for years and to go ahead
20 and follow the other guidance I have, which is to say, if
21 you can reasonably figure it out for yourself, go ahead and
22 do it. So that is what I tried to do to see how far we
23 could get. Because Farley was so much like the Surry plant
24 we have studied for a couple of decades, I thought that was
25 a good basis to make the attempt.

1 Other things that are pretty uncertain come from
2 the creep model for the RCS components. We are assuming
3 infinitely long thin wall tubes. Maybe the steam generator
4 tubes kind of fall into that category. But if you start
5 looking at things like the surge line, which we hope will
6 fail first, it has a lot of angles. It has restraints on
7 its growth. There are welds which are probably not perfect.
8 So the destructive effects may not be the ones we are
9 modeling, and if we are lucky, maybe it will fail earlier
10 than we model.
11 MR. POWERS: When you model the creep rupture in
12 things like the surge line, do you use damage accumulation
13 in the model?
14 MR. LONG: Yes.
15 MR. POWERS: Do we have damage accumulation kinds
16 of data for things that have to get that hot?
17 MR. LONG: I think somebody has failed a surge
18 line in a test, right?
19 MR. BALLINGER: This is stainless steel, right, or
20 is it carbon steel?
21 MR. LONG: It depends on which plant you are
22 talking about.
23 MR. BALLINGER: There is a lot of data for
24 stainless steels in these temperature ranges from the fusion
25 program, but not carbon steel.

1 MR. MAYFIELD: This is Mike Mayfield from the
2 staff. Surge lines are going to be either cast or wrought
3 stainless. Nobody runs carbon on the surge lines.
4 MR. BALLINGER: There probably are a fair amount
5 of data.
6 MR. MAYFIELD: We've broken them, literally a
7 surge line we got from a canceled plant, but it was at
8 normal operating pressures and temperatures rather than
9 these elevated pressures and temperatures. That is one of
10 the things we have been talking about doing in this
11 additional work that NRR asked us to do, to look at the
12 elevated temperature response.
13 MR. CATTON: Where does it fail?
14 MR. MAYFIELD: We were intentionally flawing the
15 pipe.
16 MR. CATTON: Is it the pipe itself that failed?
17 MR. MAYFIELD: Yes. Where it is going to fail is
18 where you have a crack in it, which in this case was in a
19 weld.
20 MR. CATTON: How far away from the hot leg is this
21 failure?
22 MR. MAYFIELD: This was in a straight piece of
23 pipe. It's wherever you put the flaw.
24 MR. CATTON: The surge leg comes into the hot leg
25 where everything is very thick and welded in there. It must

1 be really tough to figure out when it's going to fail.

2 MR. LONG: Also, if you take a look at the way we

3 model some of the hot legs. If we model for plants that

4 have stainless steel hot legs, we may model the safe end to

5 the vessel. The question is, is that really long thin wall

6 pipe at that point that is constrained at one end by a weld

7 of more capable material and on the other end by a very

8 thick vessel?

9 MR. CATTON: It makes this crossover even more

10 uncertain, doesn't it?

11 MR. LONG: If you start looking at the short,

12 complicated shapes, I don't think we are modeling those very

13 well at all. We are using a creep damage accumulation model

14 as if it's a thin wall pipe at the temperature that is the

15 median temperature of the full wall thickness, if I remember

16 correctly.

17 MR. CATTON: That's kind of a heat model for

18 RELAP, isn't it, just a chunk of metal with resistance to

19 the center, and the capacitance?

20 MR. LONG: Not knowing any better, I'll say yes.

21 We talking at some point about the potential for

22 the cracks eroding further by the flow going through them.

23 That doesn't look like a problem with recently acquired

24 knowledge. It certainly did sometime ago when we did the

25 last licensing applications that involved this. And the

1 same with cutting where we were using the 0.25 inch as
2 essentially a 0.25 inch through wall segment was equivalent
3 to primary and secondary failure.
4 So there are a lot of things going both ways,
5 conservative or non-conservative. We have had applications
6 claiming that the tubes wouldn't fail during severe
7 accidents even with the cracks and we have had applications
8 claiming the tubes would always fail with cracks they
9 couldn't detect during severe accidents. In either case,
10 the delta LERF is zero for what they requested. It makes it
11 very difficult to go through this and say we have done
12 everything in a conservative manner, because then somebody
13 can turn around and get the delta LERF by always failing,
14 and everything it assumes is now non-conservative.
15 MR. POWERS: One of the issues I think you pointed
16 out earlier is that when you have this steam generator with
17 natural circulation flow you have a temperature distribution
18 among the tubes of the steam generator. You look at them,
19 and you say, gee, I think these things can bow the tubes in
20 the hot zone or something. Is that what you were thinking
21 of?
22 MR. LONG: I wasn't saying they would bow towards
23 the hot zone. I was saying that if you have a large bundle
24 of tubes with a smaller batch of them at a much higher
25 temperature than the others, they would try to elongate,

1 especially if they are crimped into the support plates like
2 they would be with drilled holes, but there are other plants
3 where they are quatrefoils, or whatever. Some of them are
4 going to try to get longer than the ones on the periphery,
5 and for that matter, the shell structure. What we think
6 they would do if they are locked is bow. If they are not
7 locked, we are probably not granting credit for confinement
8 for degradation. In other words, if it's not a drilled hole
9 support plate, we wouldn't be giving them credit for the
10 drilled hole support plate, and we wouldn't have flaws that
11 would be growing to a free span. For instance, Arkansas 2
12 is a CE plant. It has an egg crate type of support plate,
13 and we treat those flaws as if they are in the free span.
14 There are a few things that I am going to talk
15 about on uncertainties further on, but I guess one thing I
16 should mention is for Farley I tried to integrate these
17 uncertainties as best I could to get one parameter for
18 decision making purposes. For instance, Charlie gave you
19 thermal hydraulic temperature uncertainty of about 50
20 degrees plus, and the way I would model that was to put into
21 the Monte Carlo process an uncertainty that was plus or
22 minus 50 degrees. I did it with a Gaussian distribution.
23 When I do things like that and I am getting beyond the data,
24 I will cut the Monte Carlo at the wings, so that if I am
25 viewing something that looks like 5 percent to 95 percent, I

1 will not let the Monte Carlo go out to three times that
2 value with some real scarce frequency.
3 MR. CATTON: Why do you give it a Gaussian
4 distribution when it's so uncertain? Shouldn't you give it
5 a uniform distribution? Isn't that the way the rules go
6 when you don't know it's equal?
7 MR. LONG: I didn't know those were the rules.
8 MR. CATTON: I don't either.
9 [Laughter.]
10 MR. CATTON: I'm just a thermal hydraulics guy.
11 MR. POWERS: When you put things on a Gaussian
12 distribution, you do need to be normalized.
13 MR. LONG: When we say we normalize, I am
14 basically putting 100 percent of the area under the
15 distribution. If I find something outside that, I'm just
16 choosing another one and going through.
17 MR. POWERS: If the number is outside, you just go
18 back and choose another one?
19 MR. LONG: Yes. It's not right perhaps, but given
20 that a flat distribution might he right too is wrong.
21 MR. POWERS: I would have funny results if I did
22 that. The check sums wouldn't work out. The probability
23 within that is one. When you clip the wings and not
24 re-normalize, when you integrate, you don't get one.
25 MR. LONG: What I am saying is, when I

1 reintegrate, I effectively get one the way I did it. So I
2 wasn't worried about that part.
3 MR. HOLAHAN: You effectively add additional cases
4 to cover for the ones thrown away. It comes out the same.
5 MR. POWERS: Actually it's a nice analytic formula
6 for clipped wings where Gaussian distribution is not all
7 that hard to use.
8 MR. LONG: Considering that while I was doing this
9 the Sun station somehow changed their link to the subroutine
10 that gives me double precision random numbers to the point
11 that I realized that something wasn't right and I found my
12 random numbers were coming up between 0.4 and 1.8 and had to
13 go back and get a Fortran instead of a C subroutine, there
14 is a noticeable difference.
15 MR. POWERS: An absolute truism is never, ever,
16 never, never use a system's subroutine for any numbers.
17 Ever. There are no good ones.
18 MR. LONG: I did check them and I was getting a
19 curve that looked like I wanted it to look before I used it,
20 but I did that in 1996 when I wrote the program. Then when
21 I realized something was wrong in 1999, it came very late in
22 the process and it was kind of disruptive.
23 Trying to catch up on the schedule a little bit
24 here, I think this is all I want to say about uncertainties
25 right now. The next thing was the integrated decision

1 process, and I will talk a little bit more about
2 uncertainties in that if we are ready to go to it.
3 MR. POWERS: We are scheduled to take a recess
4 here for ten minutes or so.
5 MR. LONG: It sounds good to me.
6 MR. POWERS: Why don't we recess for 12 minutes.
7 [Recess.]
8 MR. POWERS: We will come back into session.
9 Next we will hear about the integrated decision
10 process.
11 What seems to have been badly misunderstood is we
12 had a contention on the integrated decision making process.
13 I felt an obligation to allow the staff to respond to any
14 contentions that they felt they would like to on the
15 integrated decision making. Looking through the viewgraphs,
16 I see that you really didn't choose to respond to the author
17 of the DPO but rather describe the integrated decision
18 making process. Looking through it, it looked extremely
19 interesting to me.
20 MR. LONG: He did not like the Farley decision. I
21 just wanted to describe the process with a couple of slides
22 so everybody is on the same page and then start talking
23 about Farley. That was the intention. So as I said, I will
24 talk about the five principles and then Farley and Arkansas.
25 The five principles that I still haven't learned

1 to recite in my sleep are, first of all, the proposed change
2 meets the current regulations unless it explicitly requests
3 some change, like an exemption;
4 The proposed change is consistent with the defense
5 in depth philosophy. Here we are talking about tubes that
6 are basically two of the physical barriers between the fuel
7 and the public. So that is an important one;
8 That it maintains sufficient safety margins. Here
9 we are talking about strength, leak rates, et cetera;
10 When a proposed change results in an increase in
11 core damage frequency or risk, the increase should be small
12 and consistent with the intent of the safety goal policy.
13 MR. POWERS: Do sufficient safety margins include
14 the time the operator has available to respond?
15 MR. LONG: Not explicitly in the sense that that
16 is not one of the safety margins that is in the design
17 basis. We talked about this. In trying to interpret what
18 defense in depth was, if your cut set comes to everything
19 works fine except you are relying on the operator, that is
20 not much defense in depth. So it comes down to how much of
21 the system do you really need to work right and how much
22 damage can one of those barriers give you, whether it's the
23 operator training or action, or whatever.
24 The impact of a proposed change should be
25 monitored using performance measuring strategies. Well,

1 some of these things are to take the steam generators out of
2 service and throw them away and put in new ones at the end
3 of the period of operation where they are requesting to not
4 do another inspection. It makes it kind of hard to figure
5 out if you were right about the degradation over the last
6 cycle.
7 Then there is consideration of uncertainties and
8 their potential effects on the decision, which I will try to
9 touch on again.
10 If we are clear on the principles, let's just dive
11 into Farley.
12 MR. POWERS: Let me make sure I understand. On
13 this plus point, this is not a requirement? This is
14 guidance to people who would care to make an application
15 under the guise of a risk-informed change to the licensing
16 basis?
17 MR. LONG: When you say a requirement, Reg Guide
18 1.174 is guidance, not a requirement. The whole process is
19 voluntary. But in it there are these five principles and
20 then there are some things that the guidance says they
21 should address, including the uncertainties.
22 MR. POWERS: If I came to you with an application
23 in which I had not considered uncertainties or their
24 potential effects on the decision and made a persuasive case
25 on why that was reasonable, staff would give it the due

1 consideration it deserved, right?

2 MR. LONG: I would always give it the due

3 consideration it deserves as soon as we have time. For

4 instance, I mentioned earlier South Texas has an application

5 in. They have tried to argue the tube support plates will

6 not move from the degraded portions of the tubes by more

7 than 0.15 inches, and they made the statement that they can

8 show that the probability of rupturing a flaw is 10 to the

9 minus 14th, assuming they have a flaw under every one of the

10 tube support plate intersections and that they all get

11 exposed by 0.15 inches. The way they did this was to take

12 the 0.15 inch length on the rupture correlation and figure

13 out how many sigmas there were to get down to the steam line

14 break pressure and then figure the probability of getting

15 there. I believe it was 10 to the minus 20. And then put

16 in something like 47,000 intersections that all had that

17 probability, and wallah, 10 to the minus 14. So the comment

18 back was we didn't think they properly considered the

19 uncertainties which were really controlling from the support

20 plate deflection calculation, and for that matter, the

21 ability to detect the flaws going beyond the support plate.

22 So, yes, we do look at the way they do things. We

23 get some amazing stuff in applications.

24 MR. BALLINGER: How much more amazing than that?

25 MR. POWERS: We got 10 to the minus 45th

1 probability of welds failing in the BWR. These guys aren't
2 even in the plausible lead right now.
3 MR. LONG: They did not consider the half life of
4 protons.
5 For Farley, this is the first time we tried to
6 apply this to the steam generator tube degradation issue.
7 As I mentioned earlier, Farley really didn't address the
8 principles in the reg guide, so I tried to go through and
9 elicit information with questions and write up an SER that
10 would be more like the guidance we never got out to the
11 licensee.
12 Based on their projection of the condition of
13 their tubes at the end of the cycle, they are projecting a
14 99 plus probability of withstanding design-basis accidents
15 of tube rupture and, I think, steam line break pressure
16 differentials. They were projecting a 90 percent
17 probability of withstanding severe accidents, which we kind
18 of agreed with in the calculation.
19 MR. KRESS: What does that mean, withstanding?
20 MR. LONG: Not having a thermally induced tube
21 rupture. Pressure induced didn't matter much here if you
22 believe the first bullet.
23 The condition of the tubes was projected to have
24 about a 50 percent probability of meeting the three times
25 normal operating pressure delta P. Deterministic process

1 would normally require 95 percent, and that is really the
2 reason they were putting in the application.
3 I did the projected LERF, as I have tried to
4 describe, putting in the uncertainties to get out one number
5 as opposed to trying to get out a distribution and figure
6 out what to do with the distribution against the numerical
7 guidance in 1.174, and it met the guidance by about a factor
8 of two. It's not a big factor.
9 MR. HIGGINS: Which sequences did you consider for
10 that, all those different types?
11 MR. LONG: Primarily, at this point I considered
12 the one that remained at normal operating pressure. We had
13 discounted the LOCA sequence on the basis of their seals and
14 some other thermal hydraulic changes that Charlie had made.
15 MR. HIGGINS: Was it just the high/dry ones, or
16 was it the normal spontaneous tube rupture or the thermally
17 induced one?
18 MR. LONG: Which question are you asking me about
19 here?
20 MR. HIGGINS: Number four.
21 MR. LONG: The primary contribution to number four
22 was from the thermally induced ruptures, because what they
23 were projecting was degradation that really would not be
24 susceptible to anything else with much probability. They
25 were 99 point something probability of not having a

1 degradation sufficient to produce a spontaneous tube
2 rupture. If you put that into the equation, it doesn't
3 affect the answer.
4 As I point out, the impacts were not monitorable
5 in this case because they were going to discard the
6 generators after the operating cycle, without inspection.
7 However, the way the tech specs work right now, they are
8 fairly weak because they are designed for the wastage. What
9 we did do was to use the Reg Guide 1.174 rubric to say if
10 they sustained some sort of leakage or other effect on the
11 steam generator tubes that indicate the degradation is not
12 as projected by them to get this license change, then in
13 accordance with the principles here they should go back and
14 do the inspection necessary to return it to that condition.
15 So we added a little bit of tooth to the amendment that way.
16 MR. CATTON: What happened to four if I went to
17 two and said that was 50 percent?
18 MR. LONG: Fifty percent?
19 MR. CATTON: In other words, I just flat don't
20 know which way it's going to go. Would that have still met
21 the 1.174?
22 MR. LONG: It probably would not have.
23 MR. POWERS: It depends a little bit on what you
24 define as a LERF.
25 MR. CATTON: I think 90 percent is too high.

1 MR. LONG: Too high to require or to too high to
2 believe?
3 MR. CATTON: Too high to believe.
4 MR. LONG: Can we go to uncertainties?
5 MR. CATTON: We just went through the
6 uncertainties associated with this. There is mixing; there
7 is the fact that the hot leg is treated as a tube. All
8 these things enter in. Where does it fall down? I don't
9 know.
10 MR. LONG: I will agree with you to the extent
11 that what I was doing here was going through a calculational
12 process as best I could at the time and coming up with
13 essentially 90 percent of the core damage. The high/dry
14 accidents were not resulting in bypass by the calculation.
15 In doing that calculation, I did take a look at the
16 variation of the temperature on the tube support sheet and
17 tried to integrate that in. I mentioned in the SER that
18 that was something I tried to do and that is something where
19 we needed more effort.
20 MR. CATTON: What is done is done. I was just
21 curious how much that probability of withstanding severe
22 accident would have to decrease before you don't meet 1.174.
23 If you can decrease it to 60 percent? I don't believe it's
24 90 percent.
25 MR. LONG: Just trying to remember where the

1 numbers came out, probably if you decreased it to something
2 like 80 or 75 percent you would be over the number for 1.174
3 small change.
4 MR. CATTON: So it's iffy.
5 MR. LONG: Yes.
6 MR. CATTON: I believe it's that number two that
7 is part of the DPO.
8 MR. LONG: That's correct. That is one thing that
9 Joe Hopenfeld doesn't think is correct.
10 MR. CATTON: He questions that mixing and he
11 questions the mixing probably because he sat in on some of
12 the subcommittee meetings that took place a few years ago.
13 MR. LONG: I have to agree that I have a problem
14 with the mixing as well. Remember, this is supposed to be a
15 risk-informed, not a risk-based process. The way I
16 approached this decision was not to say I know exactly what
17 is going to go on there.
18 MR. CATTON: I understand.
19 MR. LONG: The way the stuff that we know fits
20 together now with the logic we have this would look okay if,
21 and I will get to some of the uncertainties.
22 MR. KRESS: In the Reg Guide 1.174 risk acceptance
23 values, I think there is an implication in them that this is
24 a permanent change that is going to last for the rest of the
25 life of that particular plant.

1 MR. LONG: That's true too.

2 MR. KRESS: Here you have a temporary change that
3 is going to last a short time, which tells me you ought to
4 be able to relax the acceptance criteria by some equivalent
5 factor. Did that enter your thinking at all?

6 MR. LONG: Not by a particular factor, but it made
7 me feel a lot more comfortable about doing this.

8 MR. KRESS: It made you feel better about it.
9 Okay.

10 MR. LONG: I could only be wrong for a short
11 period.

12 [Laughter.]

13 MR. KRESS: If its remaining lifetime was ten
14 years and this was only for two years, I would have taken
15 the ten over two and multiplied it times that LERF and said
16 I could increase that acceptance value by that much. Or
17 something along those lines.

18 MR. LONG: We are sort of getting into the
19 philosophy of regulation here, but I think part of it is
20 what level of benefit you are getting and what level of risk
21 you are taking to get it. We don't really trade it off that
22 way explicitly, but in previous lives, dealing with other
23 logical decisions, there was sort of a rate of risk and rate
24 of benefit that you had to balance.

25 MR. HIGGINS: Doesn't Reg Guide 177 bring that

1 into time?

2 MR. KRESS: Yes. In fact, that is sort of what I

3 would have used, the time factor that they use in 177.

4 MR. POWERS: The problem is there is no delta CDF

5 here.

6 MR. HIGGINS: No, but there are delta LERFs.

7 MR. HOLAHAN: You can't do the same thing a decade

8 lower?

9 MR. KRESS: Anyway, I think the time at risk is a

10 consideration one ought to have.

11 MR. POWERS: I guess my feeling is when you are

12 talking about a cycle on a plant, 18 months or something

13 like that, I think you've gotten all the time you can get

14 out of me.

15 MR. HOLAHAN: I agree. We have in the past, and I

16 think maybe some of Steve's other examples have time as a

17 factor. Didn't we put time in Arkansas as a factor? But

18 when you get longer than one cycle, that is too long for me

19 too.

20 MR. LONG: I guess I should say that the delta

21 LERF was factored in in the sense that if it was for a

22 fraction of a year, we annualized it to a year.

23 MR. KRESS: Yes, you usually do that.

24 MR. LONG: I like to think of this as more a delta

25 in probability over the cycle or over a year. There are

1 other people who don't like to do their math that way, and
2 we get into arguments, but to me it always seems strange to
3 talk about the frequency of something that is only going to
4 happen once.
5 In looking at the uncertainties, I talked about
6 what I tried to do with the thermal hydraulic uncertainties
7 and I basically tried to give a lot of credit to the idea
8 that Charlie was nearly right and put some wings on it that
9 went out 50 degrees in each direction and integrate that in
10 the Monte Carlo process. There are the uncertainties in the
11 mechanical properties of the materials and so on that we
12 also used in NUREG-1570, so I won't go into that. They
13 weren't that important.
14 The biggest problem was the flaw size projections.
15 The reason Farley was asking for the license change was that
16 they had had a missed signal that turned out on the next
17 inspection to be a fairly significant flaw. Now they were
18 projecting to have corrected their inspection problem and
19 have a much better process and nothing like what they had
20 found last time should show up by the end of the next cycle
21 even though they weren't going to look.
22 What I did was a sensitivity study where I took
23 their previously found flaw distribution and put it into the
24 same calculation and came to the conclusion that that would
25 not satisfy Reg Guide 1.174. So that put it into the

1 materials people's lap to try to determine if they really
2 thought the inspection process had improved enough to grant
3 this license amendment. Based on what is documented in the
4 SER, they reached the conclusion that Farley probably had
5 been able to do that, and we granted the amendment.
6 We acknowledged the uncertainty for the 0.25 inch
7 crack length that was a threshold for cutting, and I won't
8 go into too much detail because I described that earlier.
9 This was the application that pointed out to us that we had
10 to deal not just with total crack lengths but with
11 through-wall segments of larger cracks in the Westinghouse
12 process for looking at the significant segment of a crack
13 that would either pop through wall or lead to a burst in the
14 weakest segment.
15 I think that is all I want to say about Farley and
16 will go into ANO-2, unless you have some more questions on
17 Farley.
18 The ANO-2 application was ultimately denied
19 earlier this summer. The reason really had to do again with
20 the NDE uncertainty. ANO-2 had a history of doing
21 inspections finding either just barely met the three delta P
22 or just barely did not meet the three delta P criterion,
23 shortening their cycle a little bit and running and doing
24 the inspection and finding essentially the same thing. They
25 were hanging in there around the 4,000, 4,300, 4,400 psi

1 pressure capability, and they were projecting that they
2 would be able to at least do that again if not better.
3 On the other hand, they were missing flaws that
4 were fairly deep and sizable in length, and we couldn't
5 reconcile their projection with what they kept finding, nor
6 could we find any plausible reason to believe that their
7 inspection had improved with the minor methodology changes
8 they had made. So we got into a problem of projecting
9 exactly what we should put into the calculation. That was
10 one of two significant problems we had.
11 Ultimately we ended up asking them to back
12 calculate their probability of detection and tell us based
13 on their previous two inspections what they thought the
14 probability of detection was as a function of flaw size,
15 which in their case was essentially depth; they didn't
16 include length in the detectability.
17 We found that flaws that looked like they would be
18 able to actually potentially challenge the main steam line
19 break criterion were flaws that they would not apparently
20 have a good probability of detection for. That is really
21 the basis for the denial.
22 One of the things that we came up with is this
23 last line here when we started looking at the uncertainty of
24 the strength of a flaw as characterized by NDE. They had
25 some full tube data where they had actually burst the tube

1 at a particular pressure, and they had characterized the
2 burst pressure as a function of a +Point profile.
3 What we really found was to get 95 percent
4 confidence -- and I don't know why I've got 5 there -- let's
5 put it this way. If you projected the flaw to have about a
6 4,000 psi strength, to get a 5 percent failure probability
7 you'd have to go all the way down to 2,700 psi. That is
8 quite a big difference. That's 1,300 psi. I think that was
9 the first time we realized how uncertain in terms of
10 strength the NDE characterization is.
11 We also had problems in the severe accident
12 calculational process. This licensee didn't come in and say
13 that the tubes would just not fail; they came in and said
14 the tubes will almost always fail. It's a CE plant. The
15 way they calculated it and the way we calculated it seems to
16 have a higher thermal challenge to the tubes. We're not
17 quite sure why. We know that the tube sheet is closer to
18 the top of the hot leg, that the plenum is not as deep, and
19 of course the tube sheet is broader. So there is a geometry
20 difference there.
21 Also, there is a higher power than we were looking
22 at in Surry.
23 So there are a lot of things that would tend to
24 heat faster, and of course, if you are heating fast, the
25 thin things tend to keep up with the gas. The thicker

1 things don't, like the surge line. So there is more of a
2 high temperature challenge in this particular plant.
3 The licensee was arguing that they were very
4 likely to fail tubes with flaws that were 30 or so percent
5 through wall and therefore there wouldn't be any delta LERF
6 if they had any larger flaws.
7 [Laughter.]
8 MR. BALLINGER: Run that by me again.
9 MR. LONG: What they were saying is that the flaws
10 that you could expect to be present in tubes and therefore
11 would probably even be in the hottest part of the plume
12 would probably fail under their high/dry sequences if they
13 depressurized the secondary side, and therefore having large
14 flaws really wouldn't change the outcome. So the delta LERF
15 was not there.
16 They had some other sequences that weren't quite
17 so challenging and they had some small delta LERF
18 contributions from those.
19 Another thing I want to point out to you is it's
20 very hard to go through these things and claim that you have
21 done them in a conservative manner, because then a licensee
22 will come in and turn the whole thing on its ear and
23 everything that you just did that was conservative is now
24 non-conservative. If you are going to do this business, you
25 can't just run everything off to the maximum on one side or

1 your delta LERF goes to zero on either side.

2 Another thing that happened in this calculation

3 was that they had looked at some intermediate pressure

4 sequences. I mentioned earlier they did that by setting the

5 set point down to 1,400 psi early in the transient and they

6 ended up with some fairly benign situations for those as

7 well. It lowers the delta P across the steam generator

8 tubes.

9 When we tried to duplicate those, we had some

10 problems, and frankly, at the moment I don't remember what

11 they are, so I won't go into it. That is what provoked us

12 to stick the pressurizer valves open by small amounts rather

13 than full open and got us into the type of thing that I

14 described. I showed you one of those stair-step creep

15 damage accumulations for a variety of different tube

16 strengths earlier.

17 What that turned out to be for us was essentially

18 calculational overload. Instead of being able to bring the

19 process to pinch points and talk about a small number of

20 options of where the flaw might be and what the temperature

21 might be there, we were looking at a very large number of

22 potential flaws that could be affected, depending on what

23 the temperature was. We really needed to do a volume

24 integral of everything all at once, and I did not have a

25 calculational tool developed that would just go do that.

1 We weren't ready to concede to them that
2 everything would simply fail. It looked to us as though
3 this is one of the cases where MAAP turned out to be more
4 pessimistic than RELAP. We don't normally see those, but
5 this was one.
6 MR. CATTON: It must have slipped by Bob Henry.
7 MR. POWERS: I'm stunned that he doesn't see those
8 more often. Usually when they find one of those, you can't
9 get away from it. They trumpet it in front of you all over
10 the place.
11 MR. LONG: Anyway, what ultimately happened here
12 was that we really figured that we could not deal with the
13 high/dry sequences for this case. We just couldn't
14 ascertain if we thought the delta LERF was low because too
15 many of them would fail, low because not many of them would
16 fail, or high because it was right on the edge of the cliff.
17 Their option for resolving that was to adopt a strategy for
18 depressurizing the RCS.
19 I didn't bring the graph with me, unfortunately.
20 They adopted a procedure and they made a plant modification
21 to allow them to carry it out. Because the high/dry
22 sequences were dominated by a loss of one dc bus and they
23 had not two RVs like most plants, but they had a path from
24 the pressurizer to the relief tank, it was blocked by two dc
25 MOVs, one from each safety bus. They needed to get them

1 both open to depressurize. What they had to do was come up
2 with a way of whichever bus was not powered get power from
3 the other bus to open the valve that was on the dead bus.
4 They put in a procedure. They put in essentially
5 some very large extension cords and proposed to us that they
6 would instruct the operators to depressurize at effectively
7 700k or 800 Fahrenheit. We asked them to tell us how long
8 they would have to wait after that period of time in order
9 to have at least a 0.25 or lower human error probability for
10 actually succeeding in taking the action to depressurize
11 given that they might have to go out of the control room and
12 hook up the extension cords.
13 They came back with a time frame that was a delay
14 of like 20 to 30 minutes. When we ran the thermal hydraulic
15 calculations, we essentially looked for the indication they
16 were going to have an operator assigned to stand there and
17 watch for the indication on the thermocouples. We waited 30
18 minutes and 27 minutes, and RELAP opened the valve. We
19 found that it looked very capable of depressurizing rapidly
20 enough to preserve the flawed tubes.
21 At this point we had put into RELAP the ability to
22 look at stress magnification factors, and we put in
23 magnification factors up to 7-1/2, I think, which is almost
24 ready to fail at normal operating conditions. In a creep
25 damage sense, that did not look like you came close to

1 failing those tubes even if you depressurized the secondary
2 side of the generator. I think at the end we had actually
3 melted the surge line and still hadn't brought the tubes
4 that would come close to the three delta P to failure.
5 So that looked like a successful process to us,
6 and that looked like they were on the way to some sort of
7 approval except they had the problem with the main steam
8 line break type of accident and not being really able to
9 demonstrate they could find the flaws that would threaten
10 during that accident.
11 I think that as far as I went on that one as well.
12 Are there any more questions on Arkansas or on the
13 integrated decision process or how it relates to the DPO?
14 MR. POWERS: I don't think so.
15 MR. HOLAHAN: From what Steve has done and from
16 the complexity of the earlier discussions it is pretty clear
17 that if we are doing anything as difficult as these cases,
18 we are not going to do a generic analysis and say, yes, our
19 generic insight is that this sequence is important and this
20 one isn't. They are far too plant specific, and in fact
21 they turn out to be often cycle specific, because you have
22 to have pretty good insights as to the latest inspection
23 information so that you have good information on the flaw
24 distributions and things like that.
25 So even though we feel good about having increased

1 our capability of dealing with these sorts of issues, they
2 are very difficult to do, they are very time consuming, they
3 are very plant specific, and one hopes not to have to do
4 this sort of analysis often. We would prefer to have steam
5 generators with fewer flaws and maybe not quite being pushed
6 so hard.
7 MR. LONG: I hope I have conveyed some of my
8 discomfort level in trying to do these things. They really
9 are in an extremely uncertain area and it's difficult to say
10 that you have done something like this in a defensible way.
11 In terms of risk informing something, I think you can
12 honestly say if we are doing it today, this is our best
13 guess at what the answer is in risk space, but I don't think
14 we are ready to come close to being risk based in this
15 particular area.
16 The other thing I would like to acknowledge and
17 comment on is you notice there was a backfit here to
18 depressurization to avoid the LERF component from a high/dry
19 sequence. That was the thing that we supposedly did a
20 generic backfit analysis on back in the days of rulemaking
21 and decided that, gee, we couldn't see a backfit that would
22 be justifiable on the basis of the LERF component from
23 high/dry even if all high/dries are LERF. I think that sort
24 of calls that conclusion into question a little bit, because
25 it really had to go to, well, how much does it cost to make

1 the change that might be beneficial. I think we have here
2 an inkling that it's not too difficult to be pretty
3 beneficial.
4 MR. STROSNIDER: One other comment with regard to
5 these two plant-specific amendments to make sure it is clear
6 to everybody. The degradation that was of concern was not
7 involved with Generic Letter 95-05. It was other forms of
8 degradation that was driving these analyses.
9 MR. POWERS: We come now to the section of the
10 agenda that involves a summary. Before we get into that
11 summary, I will relate just a little bit of an anecdote to
12 people.
13 As you might have suspected, I have spent the week
14 having people sidle up to me and saying, how is the DPO
15 stuff going?
16 [Laughter.]
17 MR. POWERS: And I have given them a very positive
18 response. I said to them I think it's going extremely well,
19 and I think the reason it's going extremely well is we are
20 getting outstanding presentations from the NRC staff and got
21 an outstanding presentation from the DPO author. Since I
22 notice not all managers but several managers are here, I
23 hope you will pass on to your staff and, if you have the
24 opportunity, the DPO author that I think you guys have done
25 a bangup job presenting this material. It's just an

1 outstanding job, and I think I have gotten that same sense
2 from my entire committee.
3 MR. STROSNIDER: Thank you. I do appreciate those
4 comments. We will feed it back to the staff.
5 I noted in my introductory comments you were going
6 to hear from a wide variety of disciplines and people. I
7 think that indeed we do have a very dedicated and
8 professional staff.
9 MR. POWERS: I think you should be very pleased at
10 the way they have been able to work together on these. We
11 see an unexpected amount of coordination between the
12 disparate disciplines.
13 MR. STROSNIDER: It's a real statement about the
14 movement towards risk informed. We have got metallurgists
15 asking questions about LERF and CDF, and we have got risk
16 assessment people coming down and asking about metallurgy,
17 and it has been very beneficial.
18 MR. POWERS: The difference is the metallurgists
19 get answers.
20 MR. BALLINGER: Both are black arts.
21 [Laughter.]
22 MR. STROSNIDER: This suggests that I am going to
23 give a summary of steam generator issues. I'm not going to
24 summarize the last three days.
25 MR. POWERS: I thought you were going to write our

1 report for us.

2 MR. STROSNIDER: I would like to make some brief

3 conclusionary statements and maybe just touch on a few

4 thoughts that I hope people will carry away from this

5 meeting.

6 First, I want to emphasize that the staff does

7 take the DPO issues and steam generator issues very

8 seriously. When I put this viewgraph together it was

9 intentional in the title there where I said "DPO/Steam

10 Generator Issues." You heard a lot of stuff in the last

11 three days. Some of it is directly related to the DPO and

12 intended to address that, and as I said in the introduction,

13 some of it goes beyond the DPO.

14 There has been and remains something of a

15 challenge of identifying exactly what is in the DPO and what

16 other issues the staff may have taken on as a result of some

17 of the rulemaking exercises and our improved understanding

18 from a risk-informed perspective and trying to move that

19 forward.

20 Regardless of whether they are DPO issues or other

21 issues that the staff is pursuing, we do take them

22 seriously. A couple examples here.

23 There is an extensive amount of documentation on

24 these issues. I think somebody said 89 pounds.

25 MR. BALLINGER: To be exact.

1 MR. POWERS: And it is going up.

2 MR. STROSNIDER: There has been a lot of thought
3 and a lot of work that has gone into this. I will come back
4 again to the offer and before I do finish we will talk a
5 little bit about future coordination. Where the staff can
6 be of assistance in helping to point to the right reference
7 and the right section of a reference to help answer any
8 questions you've got, please let us know.

9 Development of regulatory framework. I didn't
10 plan on getting into a lot of detail on this, but as we move
11 forward in the new framework that is being developed with
12 the NEI 97-06 guidelines and tech spec change framework we
13 are taking these things into consideration.

14 I gave a few examples the other day where, for
15 example, the industry wanted tech specs that would allow
16 them to establish repair criteria, that would allow them to
17 establish repair methods. We said, no, you need to bring
18 those into NRC for review and approval. The reason for that
19 is we want to make sure that we can look at the kind of
20 issues we've been talking about.

21 With regard to the plant-specific evaluations,
22 Steve just went through two of those. I think the main
23 point I wanted to make there is that the staff, number one,
24 said that we were going to consider these things. Some of
25 the resolution of the way we are addressing the DPO issues

1 is we said we are going to consider them in our process.
2 As I said the other day, we never know what the
3 next alternate repair method or the next risk-informed
4 amendment is going to have in it. We did consider them, and
5 we can get into some discussions about do we have the best
6 models, can we improve on them.
7 The answer is, yes, we can improve on them. But
8 we did consider them, and I think we demonstrated that the
9 NRC staff and NRC management is willing to make some tough
10 decisions following these guidelines. When we denied the
11 Arkansas request, they shut down for something like two
12 months before the scheduled steam generator replacement
13 outage to perform a steam generator inspection. That is not
14 a decision that can be made lightly. It wasn't, but we put
15 it through this process. We considered the risk insights
16 and we made that decision.
17 With regard to research activities, I think you
18 have seen through the last couple of days that we have also
19 had very close cooperation between NRR and the Office of
20 Research. Where we see that we need to make improvements,
21 where we can improve in our models and where we want to do
22 that in order to apply it in the licensing process we are
23 asking them for assistance. We talked about the tube
24 cutting, and they came back with some very good information
25 this past week to address that issue. We have asked them

1 now to look at the vibration issue, and they are doing that.
2 We all have the users meet, which covers a broader
3 spectrum of risk-informed issues, ranging from the thermal
4 hydraulics to some of the tube failure, the surge line
5 response, and whether the creep modeling there is as good as
6 it should be.
7 Where these issues come up we are taking them
8 seriously; we are pushing toward resolution on them. When I
9 say resolution there, I guess maybe the thing to say is
10 improve our understanding in some of these areas.
11 Maintaining safety. During Ken Karwoski's
12 presentation he put up a viewgraph demonstrating that the
13 number of tube leaks and forced outages has decreased,
14 depending on when you start looking at that. If you go back
15 into the 1970s or early 1980s, there has been significant
16 reduction. But I think we do need to give some credit to
17 the industry, and I think the NRC staff has also had some
18 influence on that. People are applying improved
19 technologies today and I think there is some benefit there.
20 Risk-informed approach. As you can see, we are
21 moving into that. We have applied it now in several
22 licensing actions. I think those insights are helping us to
23 maintain safety. This last example where Arkansas
24 identified what they could do to reduce the frequency of
25 high/dry events and help out with that is a good example of

1 how this is helping to maintain safety.

2 I think everybody hopefully has heard and is aware

3 that we have four management goals. You can find them in

4 our strategic plan: maintaining safety, reducing

5 unnecessary burden, improving public confidence, and

6 improving efficiency and effectiveness in the realism of our

7 decisions.

8 Given those four outcomes, maintaining safety is

9 the priority. I hope that when people see the approach that

10 we are taking that they will appreciate that that is our

11 perspective.

12 Future actions. Shortly after the Indian Point 2

13 tube rupture on February 15 the NRC initiated a lessons

14 learned task force. It's another multidiscipline,

15 multi-office effort. We expect to see the results from that

16 report shortly.

17 We also have a report that was done by the Office

18 of Investigation which has some observations in there.

19 We are taking those reports and we will be looking

20 at where we can improve our processes internally, and we

21 will also be looking at what areas we need to address with

22 the industry in terms of improvements that can be made.

23 With regard to the NEI 97-06 license change

24 package, that was put on hold after the Indian Point 2

25 event. That was a conscious decision that we didn't want to

1 go forward with approving that framework methodology until
2 we understood the lessons learned and could factor those
3 into our review.
4 MR. POWERS: One of the issues that I have been
5 wrestling with is whether to try to factor in the Indian
6 Point 2 event and the lessons learned into this DPO
7 resolution process. I understood you all had been resisting
8 doing that, because at 89 pounds one more piece of paper did
9 not seem to be an absolutely essential thing, but I would
10 appreciate your perspective on whether we should or should
11 not be looking at the event and anything that comes out on
12 the lessons learned.
13 MR. STROSNIDER: It comes back to the comment I
14 made earlier, which is that it has been somewhat of a
15 challenge to define the scope of the DPO. When you look at
16 the root cause and when you look at what we are pursuing in
17 this area, I would point to the inspection report and the
18 proposed enforcement action that is under consideration now.
19 It has to do primarily with licensees following Appendix B,
20 the quality of their program, actions they could have taken
21 with regard to improving the quality of the data, following
22 up after they found an indication that was similar to the
23 one that failed, and some actions like that.
24 I don't see that those were areas that were
25 addressed in the DPO. There are some broad issues in the

1 DPO about probability of detection and eddy current testing.
2 When you go back and look at a lot of that which was raised
3 in the context of initially the voltage-based approach, I
4 don't see that it was something directly raised in the DPO.
5 Whether you want to take a look at what is going
6 on there to inform just what is going on with steam
7 generators in general, that is another question. As I said,
8 we will be coming out with reports in that area in the near
9 future.
10 MR. HIGGINS: Is there anything significant that
11 is coming out generically from Indian Point, or is it mostly
12 plant-specific items?
13 MR. STROSNIDER: The industry is doing a lessons
14 learned effort on this as well as the NRC. One of the
15 things clearly that is being looked at is generic
16 implications. If you go back and look at this failure, one
17 of the main contributing causes was poor quality of the eddy
18 current data. They missed a very large indication. A
19 hindsight review, knowing where it failed, they went back
20 and looked at the data that had been taken in the inspection
21 prior to the failure. They were able to see this
22 indication. They went to some higher frequency eddy current
23 data that made it easier to see.
24 There are some techniques that can be used to
25 enhance that, using higher frequency eddy current. Some

1 plants have already gone to those higher frequency probes
2 and doing the U-bend inspections. We had a meeting with the
3 Nuclear Energy Institute and the Electric Power Research
4 Institute. They are going back and modifying the EPRI
5 guidelines on qualification, and they are going to address
6 this data quality issue.
7 So, yes, there are some generic implications.
8 During this outage season when the staff is talking to
9 licensees that are doing inspections we are asking them what
10 they have done to address the lessons learned from Indian
11 Point.
12 With regard to 97-06, we will be re-initiating
13 that review in the near future. I think originally we were
14 scheduled to come talk to the ACRS about that. I think it
15 was at the December meeting. Don't hold me to that. It has
16 been rescheduled. Given the delay that we consciously took
17 with regard to this review, it is going to be more like the
18 March time frame, but we will be back talking about that
19 framework. We still think this is a good thing to pursue.
20 MR. POWERS: I guarantee you that if ACRS had the
21 opportunity to delay anything out of December, they did.
22 MR. STROSNIDER: I mentioned that the PWR
23 licensees have committed to follow guidelines. In fact,
24 they have done some update on their own to reflect some new
25 improvements. When we start talking about these condition

1 monitoring and operational assessment type things, this is
2 the reason that licensees are doing it. So clearly there
3 are some improvements here.
4 I guess the final thing is again I want to thank
5 all the committee members here. This is a tough area. We
6 appreciate the time and energy that you are taking to look
7 at it. It's an opportunity for the staff to hopefully see
8 some resolution to some of these issues, and we clearly want
9 to support that. Whatever we can do to help in your
10 deliberations, please let us know. I guess the process for
11 doing that would be Undine could contact me.
12 I'm afraid this probably isn't a comprehensive
13 list, but I did put together some of the things I noted
14 during the discussions that I think we owe you now. I can
15 run through that briefly if you would like to hear that.
16 The first item is to provide some more information
17 on how the Generic Letter 95-05 leakage values were adjusted
18 for pressure and temperature.
19 The second item is some additional discussion on
20 the basis for the 10 to the minus 2nd conditional
21 probability of tube failures given a main steam line break.
22 That is the criteria that is in Generic Letter 95-05.
23 We were asked to provide the distributions used in
24 Generic Letter 95-05 for analyst variability and probe ware.
25 We will provide those.

1 We were asked in the proprietary information you
2 have that shows the data points associated with the leakage
3 and the burst correlations to identify which of those data
4 points are from tubes that were pulled from the steam
5 generators versus tubes that were manufactured in the
6 autoclaves in the laboratories.
7 You wanted to see the information regarding the
8 Maine Yankee circumferential cracking. We will provide some
9 of the metallography and the pressure test data that show
10 how those type of cracks respond to that type of load.
11 We are going to see what kind of information we
12 can gather with regard to the Turkey Point event that Mr.
13 Spence discussed. Specifically, we want to find out if
14 there was post-event inspection done and what the results of
15 that inspection were.
16 MR. POWERS: Any evidence of permanent
17 deformations and things like that would be especially
18 interesting.
19 MR. STROSNIDER: Frankly, I think there must have
20 been some inspection done after that before its generators
21 were declared ready to go into service. It's just a matter
22 of seeing if we can find some of the documentation.
23 MR. POWERS: It may not be very extensively
24 documented. That is the headache you have.
25 DR. SIEBER: It was 30 years ago.

1 MR. CATTON: It was 1973, wasn't it?

2 DR. SIEBER: 1971.

3 MR. STROSNIDER: We are going to see what we can

4 find.

5 Dr. Ballinger was talking to us at the break about

6 providing some clarification on some assumptions that were

7 made in the Indian Point 2 significant determination

8 evaluation, specifically with regard to some of the human

9 reliability assumptions. We will get back with that

10 information.

11 That is the list that I had.

12 Steve, there was some discussion where I think you

13 were committing to provide some information. I didn't get

14 that written down.

15 MR. LONG: There are two more things I have on the

16 list.

17 One is the consequence difference for having 100

18 gpm primary to secondary leakage sized hole. It doesn't

19 change through a core melt accident that eventually fails

20 the RCS and the containment. That was the work that

21 Research had done. I was trying to guess what the

22 consequence relationship was to a contained accident. We

23 will get you that.

24 Also, I had made reference to some work the French

25 had done, which I think is proprietary, trying to look at

1 the effect of the crud in the crevice and the drill hole
2 support plate. We will get you something about that.
3 MR. HOLAHAN: I think we talked earlier about
4 providing some additional information on the iodine spiking.
5 To the extent we can address some of the questions that were
6 raised, for example, which data points have
7 depressurizations in them, and sort out some of those
8 issues, we will pull that together as well.
9 MR. POWERS: Let me share with you what I think
10 our schedule is going to be, with a great deal of
11 tentativeness, because, quite frankly, we won't know for
12 sure until next week. Our intention is to try to put
13 together a draft report from the panel over the remainder of
14 this month, which may have holes in it, but enough so that
15 we can pass it on to the peer reviewers we have identified,
16 who are members of the ACRS, by and large, and present it to
17 them at our November meeting. At that November meeting we
18 will give them some sort of a synopsis of what we have done,
19 kind of a status report of where we are.
20 I am allowing in that November meeting time for
21 the DPO author and the staff to make any rebuttals to things
22 that they have heard about. I've been told the DPO author
23 wants to come speak. It's not a great deal of time. We are
24 looking for fairly succinct operations. It's going to be
25 about half an hour for each side. If you care to make any

1 additional comments at that time, there is a block of time
2 available there.
3 MR. HOLAHAN: Do you know what day that would be?
4 MR. DURAISWAMY: It's November 2 at 2:30 and 4:30.
5 MR. POWERS: The peer reviewers on the ACRS would
6 have about two or two and a half weeks in November to
7 prepare their comments and get them back to us. The panel
8 will try to revise its report to accommodate their comments
9 so that we can provide a final report and maybe even a draft
10 position paper for consideration by the ACRS at our December
11 meeting.
12 Again, I suspect that we will allow time for any
13 additional comments at that time, but it will be relatively
14 brief periods of time. Just the exigencies of the FACA, it
15 seems that I have to allow time in there, but I haven't
16 figured out exactly what it is.
17 In other words, I would hope that we would provide
18 such a sterling report to the ACRS that they could move
19 forward promptly to provide an approval letter that they
20 could send to the EDO. It is my hope that we can wrap up
21 our portion of it no later than the middle of December. I
22 have no idea what schedule the EDO would operate on from
23 there. It's kind of his bailiwick. I'm moving on a pathway
24 for a prompt resolution on this right now.
25 This can be upset if in our discussions tomorrow

1 we find out that there is some glaring hole, but quite
2 frankly, I haven't seen any glaring hole. I think these
3 things have been very complete, very thorough, and very well
4 presented so that we understand where everybody stands on
5 all of the pertinent issues. I'm optimistic of meeting my
6 schedule.
7 MR. STROSNIDER: Thank you. This helps us do our
8 scheduling and gives us some idea of how quickly we ought to
9 be getting you some of this information, which we will do as
10 quickly as we can.
11 MR. POWERS: I think we will probably be making
12 changes in this report to the ACRS right up until December
13 1. Once the report gets to the ACRS, changing it after that
14 becomes troublesome to me, aside from editorial and cosmetic
15 changes. The actual report to the EDO that they make, of
16 course, is up to the ACRS. I have truthfully no control
17 over them, especially the distinguished representative from
18 Tennessee.
19 MR. KRESS: That's right. I've been known to
20 throw bombs.
21 [Laughter.]
22 DR. SIEBER: Did the peer reviewers get all the
23 documents that we got?
24 MR. POWERS: I think they have access to all the
25 documents.

1 MS. SHOOP: They got the first box. They didn't
2 get the second box that we gave to you guys today.
3 MR. DURAISWAMY: We'll send it to them.
4 MR. POWERS: Our peer reviewers are by discipline.
5 I'm not asking them to peer review all the documents save
6 what they want to say about them.
7 MR. STROSNIDER: In your discussions tomorrow, if
8 you come up with additional information or requests, we will
9 get those from Undine and we will respond to those.
10 MR. POWERS: Undine will still function as the
11 point of contact between the panel and everybody else
12 involved.
13 MR. STROSNIDER: Once again I do appreciate and
14 want to express appreciation on behalf of the staff for your
15 efforts in looking at this issue. It takes a lot of time
16 and energy, and we appreciate your help in addressing the
17 issues. Thank you.
18 MR. POWERS: Thank you.
19 At this point what I want to do is turn to our
20 consultants and ask if they have any comments at this stage
21 that they would like to make orally on what they have heard.
22 We do ask that you provide us a written report. Anything
23 you would like to pass on to us at this point would be
24 appreciated.
25 MR. CATTON: Me first?

1 MR. POWERS: Why not, you being the shy and
2 retiring type. We've got to draw Ivan out a little more.
3 MR. CATTON: That's right.
4 I think it has been an interesting exercise,
5 particularly tracking through the sequence of reports
6 written by Joe Hopenfeld. He really got better and better
7 at writing them as he went along. I was perplexed by the
8 staff's responses, because they didn't seem to change very
9 much. But the last three days I think they have done a very
10 good job. I think the response is here. The question is
11 whether or not you like the response.
12 The one area is the heatup during severe
13 accidents. I think that is fraught with uncertainty and I
14 have felt that for years. I just keep saying the same
15 thing, but there has not been much response.
16 Mixing is an issue. Heat transfer from one end to
17 the other is uncertain, and what do you do with it? It
18 seems to me you ought to assume a 50 percent probability of
19 failure of one over the other and be done with it, or you
20 have got to spend a lot of money.
21 The other area is the response of the system to a
22 steam line break, the whole blowdown process, what happens
23 inside. This is not a new issue. This was discussed in the
24 early 1970s, and one of the consultants to the Thermal
25 Hydraulic subcommittee even wrote reports on it. He tried

1 to retrieve them, but they are in Word Star, and Word Star
2 doesn't translate anymore.
3 I was impressed with what is done with the
4 relationship between voltage and burst and voltage and leak.
5 It seems to me that just bounding would put that to rest.
6 I don't see a lack of correlation like I heard. I
7 don't recall who was making the presentation, but they
8 argued for using a mean value. Leakage through these cracks
9 is just like flow in porous media. There are a whole lot of
10 parameters that are at the micro level and you are trying to
11 do something at the macro level, and your microscopic
12 variables are delta P and flow. Unless you incorporate the
13 variables at the bottom level into the equation, you are
14 never going to get it right.
15 In heat transfer we are faced with three or four
16 decades of variation for a same kind of problem. I think
17 you have got to choose the top or the bottom, depending on
18 whether you are buying or selling. In this case here it's
19 safety. You've got to choose whichever side of that band is
20 the worst. I think to put a mean through the curve is
21 inappropriate, but that's a personal view.
22 I like the process of going from the distributions
23 and how you extrapolate them all the way to either leakage
24 or burst. Some of the details in between probably could be
25 tightened up a bit.

1 I think making measurements on the pulled tubes is
2 going to help. The interesting thing is that you use the
3 voltages in situ and then you test the tubes after you pull
4 them. That can't make everything worse. So that puts a
5 conservatism in the ballgame, which I think is nice.
6 The other thing I was a little bit bothered with
7 is how you treat the iodine. I don't think there is any
8 question about the bottom line because there is so much
9 conservatism, but whenever you justify a poor model by
10 arguing conservatism somewhere else, I think you put a major
11 problem in front of yourself. You've got to deal with it.
12 You should take your best shot all the way through and then
13 add a safety factor if you are uncertain, not a huge
14 conservatism in one place to cover the bad modeling in
15 another.
16 All in all, I think it was pretty good. I think
17 the staff has really done a good job in coming to grips with
18 all of the issues.
19 MR. POWERS: Ivan, I think I and the other members
20 have a pretty good understanding of your concerns over the
21 mixing and heatup area. To the extent any written report
22 focuses an area, the more you could offer us on the
23 relationship between voltage and flow, I think that would
24 help me the most.
25 MR. CATTON: I don't know a whole lot about their

1 problem. I will put something in there. Whenever you are
2 addressing a problem that is some kind of transport
3 phenomenon in a heterogenous media, and particularly when
4 it's hierarchical from small scale to large scale, you have
5 a major headache in coming to grips with that kind of
6 problem. It is only in recent years where people are
7 actually developing the tools to do it.
8 MR. POWERS: I would appreciate comments that you
9 would like to make on the standards that you would expect
10 within your technical domain for that kind of a problem.
11 MR. CATTON: I'll do that.
12 MR. POWERS: Thank you.
13 MR. STROSNIDER: Dr. Powers, I don't want to get
14 into a whole lot of extended discussion, but we will provide
15 you some additional information. With regard to the
16 leakage, we talked about using the mean value. In fact, I
17 think what is used in 95-05 is a 95 percent confidence
18 value, but we will get you a clear description of that just
19 to make sure that there is no misunderstanding.
20 MR. CATTON: I took a look at one of those
21 figures. I don't know where I got them, but they got the
22 yellow sheet on them. And I get a really nice relationship:
23 LPH equals V.
24 MR. STROSNIDER: We will provide some more
25 information.

1 MR. CATTON: On the burst, I guess that was the
2 7/8 tube. On the 3/4 inch tube if I use 2 V, it works
3 really well.
4 MR. POWERS: Jim, I think I called you too
5 quickly. I need to ask the rest of the panel if they have
6 any questions of Professor Catton.
7 [No response.]
8 MR. HIGGINS: A general comment first. I thought
9 it was a worthwhile exercise that we all went through.
10 Looking at the stack of documents and what has happened over
11 the years, I feel that the DPO has clearly been around too
12 long and it's time for resolution and I think it's ripe for
13 resolution also.
14 I think the presentations that we got would allow
15 us to resolve most of the issues. There are clearly a few
16 things hanging out there that should be addressed either by
17 the staff or the industry. There are also some things that
18 have been indicated that are being worked now by Research or
19 NRR that need to be resolved but are under way through the
20 existing processes. I would support and I would hope the
21 rest of the committee here supports trying to resolve this
22 through the efforts that we are doing over the next month or
23 so and not just putting it off to some other committee.
24 I broke my comments up into two areas. One is
25 design basis and the other is severe accident, because I

1 think the DPO addresses both of those.

2 I think the design basis cases relate mostly to

3 Generic Letter 95-05 as far as the DPO lays it out, and

4 think that whole Generic Letter 95-05 process is very well

5 laid out and the analyses that are laid out there and the

6 bases and the background for them are good. It seems like

7 the submittals that are coming in are pretty reasonable too.

8 There were a lot of areas questioned by the DPO,

9 and without ticking them off, it seems like the staff made

10 convincing presentations on most all of those that what they

11 are doing is very reasonable.

12 A couple stick out as being questionable. One

13 that has been colloquially called the wild and wooly main

14 steam line break is one that is clearly an issue still, but

15 that looks like it's going to be treated by GSI-188.

16 Without having been able to read specifically what goes into

17 GSI-188, it seems like it may be constituted a little bit

18 narrowly to address all the concerns that were identified by

19 the DPO and that are probably legitimate concerns. It seems

20 like it may be limited to only the residents when there are

21 other displacement type of activities that have been brought

22 up.

23 The second area that seems to be open. I second

24 what Dr. Catton said about the iodine spiking. It seems

25 there is lacking a sufficient technical basis for the

1 calculation of the 335 factor and also for the 500 factor.
2 I don't doubt that there is plenty of conservatism in the
3 other areas that could account for that. Maybe that issue
4 together with the issue that we discussed quite a bit that
5 Dr. Bonaca brought up on the 30 minute for operator action
6 is a good reason to try to revisit the methodology for the
7 design-basis recalculation of design-basis steam generator
8 tube rupture analyses and to fix those.
9 On severe accidents, again it looked like the
10 staff has done a lot of work there and presented a fairly
11 convincing argument that most of the severe accidents
12 associated with steam generators have been reasonably
13 addressed.
14 It seems to me like there are three general types
15 of these. One is the thermally induced rupture after a core
16 damage event; one is the spontaneous steam generator tube
17 rupture; and the others are various transients that lead to
18 core damage from other initiators that result in abnormally
19 high DP's across the steam generator tubes.
20 It seems like they have all been reasonably
21 addressed, with a few comments, some of which pertain to how
22 you would look at severe accidents when considering Generic
23 Letter 95-05. The reason I bring that up is because the DPO
24 does bring up how you would, from a severe accident
25 standpoint, consider the things that are being done in

1 Generic Letter 95-05, and even though that may not have been
2 brought up at the time, it is certainly appropriate in the
3 current days regime of risk-informed regulation to look at
4 that.
5 It did not seem like the assumption of the
6 restraint of the Generic Letter 95-05 by the TSP was
7 adequately justified by the staff. It may be legitimate,
8 but I didn't see a good justification of it in the documents
9 or in the presentation.
10 Secondly, I heard also the staff say that they
11 believed that the CDF and LERF increases due to the Generic
12 Letter 95-05 exceptions were considered to be zero or small
13 but again did not see any quantitative presentations on
14 that. It seems like that is something that should be done,
15 and I'm not sure if it needs to be done generically or on a
16 plant-specific basis. Steve mentioned that it looks like it
17 is being done now on a plant-specific basis, and maybe, if
18 that is the case, you don't need to do it generically.
19 I would have liked to have seen some generic
20 presentation that considered the three different types of
21 severe core damage accidents associated with steam
22 generators. You can make an argument that all of those have
23 some potential of being affected by the 95-05 relaxation.
24 I guess I would also comment that the discussion
25 that we had on the HEPs and the concern that the DPO had, I

1 didn't really see a problem with respect to what has been
2 done over the various things. Even though that is an area
3 where there is considerable uncertainty and variability, I
4 felt what has been done in the various studies, especially
5 the more recent studies, is reasonable.
6 MR. BONACA: I'm sorry. Could you repeat that?
7 Reasonable regarding what issue?
8 MR. POWERS: Human error probabilities.
9 MR. BONACA: Okay.
10 MR. HIGGINS: The issue that they had raised on
11 the human error probabilities associated with the tube
12 rupture sequences.
13 There were a few other areas of the severe
14 accident that were raised by the DPO that have not been
15 addressed to date but are being addressed by the new
16 research-related areas that are going on as a result of that
17 February 8, 2000, letter.
18 That's all I had. Thank you very much.
19 MR. POWERS: To my mind all of your comments are
20 very useful. In your written report, I think it would
21 probably be of most use to the committee if you could focus
22 on what your thinking is about this 30-minute operator
23 action under your design-basis activities. Similarly, your
24 thoughts on the HEP, the more recent studies.
25 All the comments are good. If you have an

1 opportunity to focus, those are the two areas that I think I
2 could use the most help from you.
3 I will turn to the rest of the committee and see
4 if they have any suggestions.
5 MR. BONACA: Any comments on the HEP. Expressing
6 perspectives and opinions is still a soft area, particularly
7 when you get into multiple tube ruptures and so on and so
8 forth, which is really the area of concern presented by the
9 DPO. Any insights on that would be useful.
10 MR. HIGGINS: Okay.
11 MR. POWERS: We are going into a fairly intensive
12 activity tomorrow as a panel. I think we need to go back to
13 the contentions list and try to walk through those
14 individually tomorrow, deciding what we are going to write
15 and what we are going to say in something of an outline.
16 I will remind you that the author of the DPO
17 provided us a list of questions in addition to his
18 contentions, and I think I have to treat those under the
19 contention category that has been laid on the table and to
20 at least deal with them. If not as specific contentions,
21 our response should address those. So I will encourage you
22 to take a look at those questions to make sure we have
23 answers.
24 Finally, in the spirit of the point that Dr.
25 Catton made that the DPO author gets better and better at

1 articulating his point, he did conclude his study with two
2 recommendations, that Generic Letter 95-05 should be
3 withdrawn and those plants that use the alternate repair
4 criteria should be shut down. I had hoped we would not have
5 to address those, but I think we will have to give a very
6 clear recommendation in regard to both of those
7 recommendations that he has made. So be prepared to discuss
8 those as well as the more detailed technical contentions.
9 MR. CATTON: His first one was 95-05. What was
10 the second?
11 MR. POWERS: That those plants that have the
12 alternate repair criteria be shut down.
13 MR. CATTON: The 17 plants.
14 MR. POWERS: It's the ones that have the alternate
15 repair criteria, and I think in his oral presentation as
16 opposed to what he has written down those that don't go
17 immediately to the 40 percent plug-in criteria of old should
18 be shut down. I think we have to address that. I think we
19 have to give something very explicit in the report on that.
20 Do any of the members have comments they would
21 like to make, any comments on the overall strategy that we
22 would need to think about tonight? We will undoubtedly find
23 ourselves revising and honing this strategy a good deal
24 tomorrow.
25 My thought is that I will probably lose quorum

1 tomorrow about one o'clock. That is typically when I lose
2 quorum on these things.
3 We do have a little challenge getting into the
4 building tomorrow. We have to go by way of subterranean
5 passages.
6 I want to think you, Jim and Ivan. I think you
7 have added to this. I think your reports are going to add
8 to this. It is very helpful to have you here. I look
9 forward to what you have to say. As this draft report comes
10 along I will be sending you copies and looking for your
11 comments and any advice that you could offer to us. You can
12 switch hats and start playing the role of peer reviewer
13 here.
14 Any other comments?
15 [No response.]
16 MR. POWERS: Again, my sincere appreciation for
17 the quality of work by the staff and their presentations and
18 their managers. I think you've made this task a lot easier
19 than I forecasted it would be.
20 With that, I will recess, and that ends the need
21 for recording.
22 [Whereupon at 6:45 p.m. the meeting was
23 adjourned.]
24
25

REPORTER'S CERTIFICATE

This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission in the matter of:

NAME OF PROCEEDING: MEETING WITH THE AD HOC SUBCOMMITTEE ON DIFFERING PROFESSIONAL OPINION ISSUES

PLACE OF PROCEEDING: ROCKVILLE, MD

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission taken by me and thereafter reduced to typewriting by me or under the direction of the court reporting company, and that the transcript is a true and accurate record of the foregoing proceedings.

Mike Paulus/aa

Mike Paulus
Official Reporter
Ann Riley & Associates, Ltd.