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NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

SUBCOMMITTEE ON THERMOHYDRAULIC PHENOMENA

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MONDAY

SEPTEMBER 9, 2002

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The ACRS met at the Nuclear Regulatory Commission, Two White Flint North, Room T-2B1, 11545 Rockville Pike, at 1:00 p.m., Graham Wallis, Chairperson, presiding.

COMMITTEE MEMBERS:

GRAHAM WALLIS Chairman

TOM KRESS Member

DANA POWERS Member

PETER FORD Member

VICTOR RANSOM Member

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

1:05 p.m.

CHAIRMAN WALLIS: The meeting will now come to order. This is the meeting of the Subcommittee on Thermal Hydraulic Phenomena. I am Graham Wallis, Chairman of the Subcommittee. The other ACRS Members in attendance are: Peter Ford, Tom Kress, and Dana Powers. For today's meeting, the Subcommittee will continue its review of the proposed resolution of Generic Safety Issue (GSI) 185, "Control of Recriticality Following Small-Break LOCAs in PWRs".

The Subcommittee will gather information, analyze relevant issues and facts, and formulate proposed positions and actions, as appropriate, for deliberation by the full Committee. Mr. Paul Boehnert is the Cognizant ACRS Staff Engineer for this meeting.

The rules for participation in today's meeting have been announced as part of the notice of this meeting previously published in the Federal Register on August 21, 2002.

A transcript of this meeting is being kept, and the transcript will be made available as stated in the Federal Register Notice. It is requested that speakers first identify themselves and speak with sufficient clarity and volume so that they can be readily heard.

We have received no written comments or requests for time to make oral statements from members of the public. We will now proceed with the meeting, and I will call upon Harold Scott, from the NRC's Office of Nuclear Regulatory Research, to begin.

MR. SCOTT: Thank you. The same team making the presentations today (audio gap) will be providing the same thing here at this meeting. I noticed at the July meeting, you provided a remark about some things besides water in the reactor, there are neutrons. We've got some water guys, and we've got some neutron guys. The next page in your hand-out summarizes this issue. Talking about small-grade LOCAs, which have probably reduced the high-pressure injection capability, such that you get steaming in the core. That steam goes over into steam generators. It doesn't really matter whether it's a once-through steam generator or recirculating steam generator.

You build up some deep boiling water in the outlet plenum of the steam generator, the cold leg. I'll show you a picture in a little bit. Then after the system fills up again, natural replacement will restart, or the operators might start a pump.

Now this unborated water goes into the

core, and causes the reactivity surge.

DR. FORD: One of the things (audio gap) is that the (audio gap) deborated water (audio gap).

MR. SCOTT: I haven't seen one either, but if it's steam, it's going to be, you're saying that some boron might carry over with steam?

DR. FORD: It's a finite vapor pressure. It's a finite vapor pressure at these temperatures.

MR. SCOTT: Oh, okay. We didn't look at that.

DR. WALLIS: Well, your reports speak of near-zero boron.

MR. SCOTT: Okay.

DR. POWERS: Well, the question is, how close to zero are we discussing. If the systems fail to pull away or pressurize (audio gap) can't possibly be more than about one theoretical plate in the system, and it's not very close to zero.

MR. SCOTT: I would guess that we'll find out the uncertainties in mixing. We're going to swap out the question of whether it's -- what the concentration is in a so-called unborated slug of coolant water.

In your hand-out there's a --

DR. DIAMOND: David Diamond of Brookhaven.

I have seen those calculations in the past. My recollection is that (audio gap)

MR. SCOTT: (audio gap) this high-pressure blow-out (audio gap)

DR. POWERS: Dr. Kress, you have done analyses in this area. (audio gap) have a negligible (audio gap)

DR. KRESS: Well, there is a significant (audio gap) calculations where you assume the boron delivery with the steam is carried over at this pressure (audio gap) in the (audio gap) I would expect if you have a significant -- I haven't done the actual calculation.

DR. POWERS: It is crucially dependent on what pressure you're operating at.

DR. KRESS: Yes, pressure.

DR. POWERS: Well, the two aren't independent there.

MR. SCOTT: Are we down at 500 PSI or (audio gap)

DR. KRESS: Okay, if there's low pressure then --

DR. POWERS: Well, let's make sure we understand what low means. In this case I doubt we're below the pressurizer relief valve.

MR. SCOTT: In small-break LOCA, under these conditions, yes we are, at the --

DR. POWERS: You've got the accumulators?

DR. KRESS: Under those conditions it may very well --

DR. POWERS: It may be fairly well partitioned at that point.

CHAIRPERSON WALLIS: I don't like the vagueness, I would like to have some numbers on low and high and negative (audio gap)

MR. SCOTT: (audio gap) next (audio gap) probably more (audio gap) the next picture in your hand-out is a raised loop BNW machine. That one currently has a hole in its head so it's not running. This is the lower loop. And just for clarity purposes, Westinghouse (audio gap)

There's another (audio gap) and you can see there's a cold leg (audio gap) here (audio gap) maybe I should (audio gap)

DR. WALLIS: Why did you do all the calculations on one of these machines? They all have, they all have this problem of eventually they (audio gap)

MR. SCOTT: Yes, and the main issue was for the OTSG plants, because they have a larger volume.

The other guys claim that it's not such a problem, which I'll cover later this afternoon.

We have not done any Westinghouse or CE, we didn't plan to.

DR. WALLIS: Well, then I read in your report, that I read, that the Westinghouse CDFs are four times the BNW? That was surprising.

MR. SCOTT: The total -- When we do this calculation of prioritization, you have like cost divided by person-rem avoided. My recollection it was two or three times for the Westinghouse CE plants, versus the BNW (audio gap)

We would call (audio gap)

DR. KRESS: So Westinghouse CDFs are four times the BNW?

MR. SCOTT: Well I have the (audio gap) my picture here --

DR. KRESS: I don't have the page, but this was in the report that I read.

MR. SCOTT: Because this did come up last time. I think we weren't crisp -- let me just see if the numbers are here (audio gap)

DR. WALLIS: The Westinghouse number's bigger. Four times as big. It's bigger. (audio gap) So the question is why did you concentrate on the BNW (audio gap) available (audio gap)

MR. SCOTT: Yes. We think the -- If we find out that it's a likely problem for one, the implication is it's a likely problem for the other one. Or if we could show there's not a problem for the one, then it would not be a problem for the other.

And that's -- Originally we thought maybe we could show that. The Westinghouse steam generator, that we could get core enthalpies sequential and that we could do this well enough and that would (audio gap) for the other reactors (audio gap)

DR. WALLIS: Well, I don't know, I mean they're quite different in design. Volumes are different, (audio gap) sort of similar, but (audio gap)

MR. SCOTT: This is 1x10(-6)?

DR. WALLIS: Yes, that's one.

MR. SCOTT: Okay, then I'm saying that there are --

DR. WALLIS: Those are the same, but the CDF numbers were about four times what Westinghouse. I mean, you don't have to involve a reactivity expert to see the --

MR. SCOTT: Yes, but we're only looking at --

DR. WALLIS: That's all you're looking at?

MR. SCOTT: That there are ten times as many Westinghouse and CE plants as there are --

DR. WALLIS: Okay, so they're comparable, you're saying?

MR. SCOTT: Yes.

DR. WALLIS: Okay. (audio gap)

DR. RANSOM: Well, I guess you have to make the argument that this is the worst case situation.

MR. SCOTT: That was probably part of the --

DR. WALLIS: It wasn't clear to me that it was a very good argument.

MR. SCOTT: Okay.

DR. WALLIS: Maybe someone can explain that later on.

MR. SCOTT: Let me mention this. This is the historical background that Bill Vandermullen wrote in the report he did about two years ago. NRR sent over a suggestion that because of this question about the reactivity accidents in high burn-up fuel,

The criteria before say (audio gap) but the criteria's still 280 calories per gram. We have information from these test reactors in France, in Japan, and Russia, that that number for high burn-up fuel might be around 100 calories; substantially less.So we need to go back and look at these reactors for this transient, what is the enthalpy, and what would it now be if it was 200 calories per gram, that would be less than the old limit.

And I also wanted to point out, it was this high burn-up concern that triggered this. Also, the fact that if you run the pump (audio gap) that's what most (audio gap) bumping the pumps was going to give you a larger transient.

Primarily based on interactions with NRR (audio gap)

DR. WALLIS: Well the Westinghouse owner's group didn't do the same kind of analysis that --

MR. SCOTT: Well, yes and no. And I'm now going to have Professor DiMarzo start, and then David Diamond. Maybe it will be confusing if we have -- the handouts aren't here yet, but we can go get them -- if I can't answer, I'll (audio gap) I think they're ready now if we can go get them. (audio gap)

Do you want to go first? Second? Okay, you'll have your slides up here and we'll try to get the hand-outs as soon as we can. Let me answer, the question is about (audio gap)

DR. WALLIS: You seemed to have something to go on in BNW, they had done analysis.

MR. SCOTT: Yes.

DR. WALLIS: But Westinghouse doesn't seem to have done the same kind of analysis. I'm puzzled.

MR. SCOTT: Okay, and they did for AP600, and combustion did for CE80, and I'll pick that up.

DR. WALLIS: Well, how about the existing plant?

MR. SCOTT: None that I know of.

DR. KRESS: It's an issue and they didn't analyze it?

MR. SCOTT: Well, they don't have to analyze issues.

DR. WALLIS: They don't?

MR. SCOTT: It's research.

PARTICIPANT: It's a power safety issue.

DR. WALLIS: Your safety.

PARTICIPANT: BNW had commented -- they made a presentation, they had done a certain level of work which had spurred on a fair amount of creation of (audio gap)

DR. WALLIS: I guess what concerns me is if you're going to reach a conclusion that this is not an issue for Westinghouse plants, but it could be the basis for -- when should that be analyzed?

PARTICIPANT: (audio gap) By the end of the afternoon.

DR. KRESS: By the end of the afternoon?

DR. DiMARZO: Now, what is the rationale for this idea? The idea is to avoid having to go and estimate what the (audio gap) inside the vessel. In that sense, the level of involvement is quite high. But if we can avoid that, if we can try to pose the issue (audio gap)

DR. KRESS: Just assume no mixing in the vessel.

DR. DiMARZO: Now I want to assure you, something I don't have the slides for this (audio gap) get a sense of what we are talking about. You consider (audio gap) proposed by the owner (audio gap) the result of that calculation is this. (audio gap) indicate that under (audio gap) primarily goes down, from that point, some of it goes around, but there is a (audio gap)

Going down, not up.

DR. WALLIS: What we're looking at here is a downcomer?

DR. DiMARZO: Down (audio gap) operation is (audio gap) this is now cold leg (audio gap) open, unwrapped, down (audio gap) and you can (audio gap) the level (audio gap) comes through (audio gap)

DR. KRESS: We're looking right into the hot leg inlay?

DR. DIMARZO: Right into the cold leg out.

DR. KRESS: Oh, it's the cold leg.

DR. WALLIS: It's up there because it's lighter or something?

MR. DiMARZO: No, this is the totally same condition; same weights and everything. Nothing under that cold leg.

DR. KRESS: Why does it do that?

MR. DiMARZO: That I don't know, but that's what it does repeatedly. What happens actually is that it shows up -- that region remains such. The momentum that carries it around is enough. What separates the (audio gap) fact that in the downcomer there is an enlargement, (audio gap) reinforcement, penetration of the leg.

And that is the (audio gap) in other words, that is the roll-off (audio gap) number of repeat tests (audio gap)

DR. WALLIS: Is this because it's got a high velocity, so it spreads out in all directions?

MR. DiMARZO: All kinds of things, but what I'm trying to say is that there is going to be extremely complex to make scaling out from a huge scale, a large scale, it's going to be extremely complex to get the CFD code essentially validated.

DR. WALLIS: The CFD code seems to disagree with the --

MR. DiMARZO: Please. But the problem is if you are going down the road of calculating and evaluating the in-vessel, what I'm trying to show you here is that this isn't going to be a very easy, and I don't know where that road's going.

DR. KRESS: Well, you've got to finesse that problem.

DR. DiMARZO: I'm trying to say it's not going to be an easy task.

DR. WALLIS: So you're saying that is a realistic calculation.

MR. DiMARZO: First of all, it could be possible. I don't know how time-consuming and how expensive that is.

DR. KRESS: You would make a --

MR. DiMARZO: -- I don't have any idea what we --

DR. WALLIS: You want to make a bounding calculation?

MR. DiMARZO: So I'm going to say, let me talk with -- (audio gap) When I take this slide, and I try to move it through the entrance of the down pump. So all I'm interested in essentially are the pipes, the steam generator and the pipes, and the cold legs leading to the vessel.

Of course we'll see, we'll get a slug and we'll move it through.

The key feature of the model, keep in mind that this is just the model. We see that in all the systems there are two things involved. One is the pump. (audio gap) the reasoning for that, here you're coming out of the tube, you're borated, actually you have jets of borated water, therefore this jet will mix. This volume, in the end, will be completely mixed. Inlet situation will happen in the pump due to the (audio gap).

DR. WALLIS: You're saying that vessel (audio gap) criticality (audio gap) theory, and here you have theory with no experiment at all.

(audio gap) dead air on CD (audio gap) the legs you transport, you just move this blocked flow, and then in those volumes you have so-called back-mix (audio gap), which basically means the steaming volume.

And you add those three in. This is the

transfer function for such a volume. Where C NOT (audio gap) is the initial concentration, C lambda is the historical concentration that you can put him in, and C theta is a function of this time, is the concentration that gets out of the pot. That's just old stuff, mechanical engineering reactor. So it's a very simple model. Now how do we do it? So, there were some tests performed at Maryland a long time ago that basically had a situation where the system was full of warm water. An interesting pictorial so you can understand what was done. System is full of hot water, up to a point. Now you are going to introduce, from the bottom of the cold legs, actually from here, cold water, changing.

And so you have a lump of cold water, like there. But up to the same elevation. There is water above that. There is warm water above that. So that is a way to simulate the temperature, a situation like in concentration.

It's that accurate in that you have a transfer to go on, but that's mine.

DR. KRESS: That assumes that all the transfer takes place --

DR. DiMARZO: Yes, you have a mixing process, and temperature is your figure of measure, as opposed to concentration.

DR. KRESS: The thermal conductivity --

DR. DiMARZO: It's a thermal mix, between -- a slug of cold water and warm water above.

CHAIRMAN WALLIS: Now, this black stuff here, this is --

MR. DiMARZO: Cold water.

CHAIRMAN WALLIS: And cold water fills legs and part of the steam generator.

MR. DiMARZO: And part of the steam generator.

CHAIRMAN WALLIS: On the outside of the tube.

MR. DiMARZO: No. This is inside of the tube.

CHAIRMAN WALLIS: Then on the outside of the tubes you have the --

MR. DiMARZO: Same. These are the -- It's just a --

CHAIRMAN WALLIS: So, why are you introducing something at the bottom there? Where is it coming from?

MR. DiMARZO: I put something in the cold leg and I let it rise, pushing the warm water that was there up.

CHAIRMAN WALLIS: So where's it coming from?

MR. DiMARZO: Oh, from a pipe.

CHAIRMAN WALLIS: No, I mean, in terms of simulating the reactor.

MR. DiMARZO: Oh no, this is to validate the model. And dealing with a --

CHAIRMAN WALLIS: We aren't simulating a scenario at all?

MR. DiMARZO: We haven't done anything of that yet. We are saying, I want to model the transfer of a slug with that simple model. So let me make a slug in a geometry that's reasonably close to what we're dealing with, and validate that model.That's all I'm doing. It doesn't have anything to do with pressure distinction. It's just a -- You said, this is just a model. I can now make some data to show you that the model is somewhat reasonable.

CHAIRMAN WALLIS: You're in a place where you say there is perfect mixing?

MR. DiMARZO: I put this cold water in, very gently, and what I'm saying now is that this water here, when I move it, we'll see, this prong, we'll see the two-prong mixing volume, while the tail, which is down back by warmer water.

We'll see the outer plenum first, as a mixing volume, and after that the pump. So, the front of this slug will go through, just the pumps. So it will be mixed relative to that volume.

The tail of this slug will go through the steam generator of the plenum, and then successively after the pump. So it will see two stages of mix. All right?

Now this is summarized --

CHAIRMAN WALLIS: By "slug" you mean the slug you injected --

MR. DiMARZO: That cold water mark.

DR. POWERS: Now just to be clear. You're thinking the -- with this simulation the cold water represents the borated fuel?

MR. DiMARZO: Well, you could say that or you could not. What I'm only trying to say is to validate the transfer mixing model. We could do that completely in thermal, or we could do that -- You know, I could do any kind of thing.

I'm just simply stating, in that geometry, or in something that looks like that geometry, let's see if such a simple model based on very simple analysis, gives us a reasonable result. That's all I'm trying to say.

There's no relationship to the issue yet. Okay? I'm just building myself a tool to analyze the more complex situation later. This is the comparison with the data. Now, the front is obviously sharper, the data is obviously the top, and the line is what you get out of that model.

The front is clearly sharper because you're going only to one mixing model.

CHAIRMAN WALLIS: Are you measuring this at the outlet from the pump?

MR. DiMARZO: I'm measuring this at the downcomer inlet.

CHAIRMAN WALLIS: You didn't show that in the previous figure. So it's the outlet of the pump?

MR. DiMARZO: But let's face it.

CHAIRMAN WALLIS: When you say it was set by using electrical --

MR. DiMARZO: This is a temperature in the tank, okay?

CHAIRMAN WALLIS: So why is the first slug just that black stuff? I don't understand -- Why doesn't it just drive that black stuff up to the top of the building to start with.

MR. DiMARZO: This thing goes through here, no mixing at all, it's just a half, a top half distribution up to here. Then it comes in here and steers that little volume. And through the transfer function comes out --

CHAIRMAN WALLIS: What is it mixed with?

MR. DiMARZO: It has been cut off, it is directing warm water above it.

CHAIRMAN WALLIS: Oh, there's another water on top.

MR. DiMARZO: Yes, yes. This is injected under the cold water which is displaced up.

CHAIRMAN WALLIS: So the black stuff is the injected stuff? I thought it was --

MR. DiMARZO: Gently inserted --

CHAIRMAN WALLIS: I'm sorry, I thought this was the starting condition you showed us here.

MR. DiMARZO: Absolutely.

CHAIRMAN WALLIS: But it's not.

MR. DiMARZO: But above it all the white represents warm water.

CHAIRMAN WALLIS: So you've already injected some stuff when you're showing this picture? Yes.

MR. DiMARZO: The system is full of hot water. I am putting gently through the cold water in.

CHAIRMAN WALLIS: And it's filling up from the bottom.

MR. DiMARZO: And then I move it.

CHAIRMAN WALLIS: See I didn't understand. I thought you said this was the initial condition, and then you started injecting.

MR. DiMARZO: No, no.

CHAIRMAN WALLIS: No.

MR. DiMARZO: I put that in place, I turn on the pump. And then I measure the temperature provided at the entrance of the pump. That's what you get. First you see the front come into it. The trunk has been mixed into the pump only.

Then comes the tail. The tail mixes with the steam generator of the plenum. Because now the steam generator of the plenum is totally engulfed in the so-called deborated, or cold water.

CHAIRMAN WALLIS: That's because it's come down from the steam generator.

MR. DiMARZO: It's coming from the steam generator, and sees now this colder water, but it's coming into jets, into that, and mixes. The result of that is that there's some mixing.

Then all this mixed front transfers through the pump, and therefore gets --

CHAIRMAN WALLIS: Okay, now let's get this straight. It's flowing because you turned the pump on. It's not flowing because you injected.

MR. DiMARZO: Right. And so this is now saying that as long as you turn on the pump and everything and the mixing is such and such, this model, this very simple crude model, does a very good job.

DR. KRESS: You had to apply the model in two places?

MR. DiMARZO: Yes. Two mix --

DR. KRESS: Combine the solutions of those two.

MR. DiMARZO: Remember that this saturates completely, so there is no information passing from the front to the tail. Now --

DR. KRESS: Physically, why does the temperature go down?

MR. DiMARZO: Here?

DR. KRESS: Yes.

MR. DiMARZO: Because this is all upside down. We are going cold. If this was in terms of temperature it would look like this. Going up. The cold water is 20 degrees, the rest is maybe 50 or so.

So this here is 50 and this down here is 20, something like that. Okay? And then all this --

DR. FORD: And it will go up?

MR. DiMARZO: It will go up again to whatever this water mixed with the other water, whatever that is. Slightly less than 50, because we now introduce this --

DR. KRESS: It will eventually approach that.

MR. DiMARZO: Eventually.

DR. KRESS: If you've got an infinite amount of hot water --

MR. DiMARZO: Eventually. I mean if it was all cold water, huge system, it would go to 50. Right. So this is the model that I'm going to now use to get an estimate in the reality.

Why am I doing that? Because the geometry is long, so to speak. It's not that different in scale since we're only dealing with volume. It's either fully mixed or zero mixed. So there are no -- how can I say -- issue associated to partial mix. It's either all or none.

So if all that matters is how big is that volume where all happens. Now one can argue does clearly all the plant volume mixes or not? And that's an argument that remains unvalidated.

DR. FORD: Don't you have a problem with --

This is a very simple model.

MR. DiMARZO: Yes.

DR. FORD: Applied to a very simple geometry. And it works. Why didn't -- See now you're making the assumption, applying it to a more complex --

MR. DiMARZO: With downcomer I wouldn't even dare to do this, because downcomer is a much more complex situation, because you have a partial mix. Whereas this indicates that the steam generator of the plenum pretty much is all mixed, because you have all these jets coming out of the tubes.

And the pump volume, especially when the pump dries.

DR. KRESS: Basically, the model event is you have volume, and you're injecting some stuff into it. Each increment that goes in there instantaneously gets fully mixed. And that's the basis that you get these transfer functions from.

If you use that and you're flowing out at the same rate, a different concentration. So if you take that you'll get this transfer function.

MR. DiMARZO: And it doesn't work that bad.

DR. KRESS: Yes, that's pretty good.

MR. DiMARZO: That's all I'm saying.

CHAIRMAN WALLIS: So the black stuff was cold water?

MR. DiMARZO: The black stuff was cold water.

CHAIRMAN WALLIS: So one reason the hot water stayed on top of it was because it was lighter?

MR. DiMARZO: Because it was lighter, absolutely.

CHAIRMAN WALLIS: Which doesn't happen with your borated water quite the same way.

MR. DiMARZO: We can see. We have a number of tests in all kinds of situations with salt, and steam pressure to do --

CHAIRMAN WALLIS: But your cold-hot is inhibiting mixing.

MR. DiMARZO: Yes, absolutely.

CHAIRMAN WALLIS: Is that realistic in terms of what the borated water would do?

MR. DiMARZO: It would be like a tube. The same thing. The cold water against the deborated water is like salt water against --

CHAIRMAN WALLIS: So in the steam generator there would be more mixing.

MR. DiMARZO: Yes, so it would be conservative.

CHAIRMAN WALLIS: Would it be conservative?

MR. DiMARZO: Yes, but there would be borated water mixing that you --

DR. KRESS: Concerning from the standpoint of -- he wants to know how much boron is in the tank.

CHAIRMAN WALLIS: So generally the idea is the more mixing you have --

DR. KRESS: The more boron you've got going in --

CHAIRMAN WALLIS: The less conservative.

DR. KRESS: No, the more mixing is --

MR. DiMARZO: The more mixing is less conservative.

DR. KRESS: Yes.

CHAIRMAN WALLIS: The worst thing would be to have no mixing.

MR. DiMARZO: If it's very sharp, it's working. As you will see in a minute. So now, this doesn't have anything to do with the issue. Now we go into the issue.

CHAIRMAN WALLIS: It doesn't have anything to do with this?

MR. DiMARZO: It's just a model.

DR. KRESS: Well, it's a way of finding out how much boron is going in.

MR. DiMARZO: It's a way to deal with -- Because last time it was suspicious when we got boron back at this time. What is the other group coming up with?

They come up with a slug of 22.3 meters cubed. They come up with a presumption of natural circulation at a rate of 0.2 meter cubed percent. They state, this is how fast the steam can move through.

I show you how they got that. I am not interested in spending a lot of time, neither are you, because we're going to do a bounding case which is much worse than that.

But anyway, they build up a scenario for which they build up a slug, or an initial condition. And then they proceed to move it at that rate through the vessel. Through the pipe, through everything.

So what do they do? Well, this is important, because in a way builds up to higher, evolved, natural circulation scenario. So, in that sense, it's interesting.

You've got this break. Obviously, the pressure drops down, at CP entry. Now, eventually your HPI injections are deficient compared to the break flow, so your inventory drops.

At some point, you go to two-phase natural circulation, which carries over water over the candy cane, at some point the level drops even further, and it is impossible for this water to make it through.

At that time, BCM initiates. So you're basically pouring the water in the basin, generate vapor, the vapor travels through the candy cane, into the steam generator. You have a secondary slug elevation which is above the level of the meter.

That as a condensing surface exposed, that vapor condenses on that condensing surface, and because it's on top of what's there. That is the mechanism by which you're going to generate the deborated, and we have to add the water concentration on that BWOG and so forth, but we will document it.

So you pick up that thing, basically one hour, less than an hour, something on the order of one hour, gets you this deborated.

CHAIRMAN WALLIS: It would be nice if you had a figure showing the sort of state of things at that point.

MR. DiMARZO: I do.

CHAIRMAN WALLIS: Okay.

MR. DiMARZO: This is just what they presented. So I'm getting to that when I do my next slide.

CHAIRMAN WALLIS: Well, we have to visualize what's going on.

MR. DiMARZO: Okay, I will jump ahead.

MR. SCOTT: But there, in order to get to where he's at now --

MR. DiMARZO: Yes, yes. The maximum you can do is this. You are fielding all that volume, roughly speaking, of deborated water. And one can argue how exactly this level is.

CHAIRMAN WALLIS: So it's the worst it could be.

MR. DiMARZO: That's the worst it could be.

DR. KRESS: Is that the 23 cubic meters?

MR. DiMARZO: No, no. That's much more. That's why --

DR. KRESS: That's much more.

MR. DiMARZO: It gets confusing to jump ahead. If you let me go with my slides it will be more clear.

CHAIRMAN WALLIS: No, actually what I was asking for, was it's nice to have a figure showing how the condensation is happening and I guess, I'm not saying you have to do it now, it would just be nice for the presentation to -- we have to visualize how it's happening.

MR. DiMARZO: I see. It's somewhere. Okay. So the secondary slug is roughly speaking at this elevation here. The primary slug is somewhat below that.

CHAIRMAN WALLIS: Why the lowered loop is worse, because you have more places to collect the slug.

MR. DiMARZO: That goes exactly to your original question of why this is --

CHAIRMAN WALLIS: Why was it?

MR. DiMARZO: The problem is not conforming, only to confirm it in any plan. The problem is that you've got the segregated into the plan ready. Because in order to move it, a lot of other things have to happen.

And I'll go back to the original slide and show you what has to happen before we can move it. So in order to form it it's fine, but then you've got to have a storage place to hold it there, until you are ready to move it.

And that limits severely what the impact is on your other plants. So now here we go with the continuation of the scenario that the other group put forward.

So at some point now, the BCM is finished, you've got all this water packed up in that volume, you've got lower portion of the primary system on the steam generator side.

And something else, for which now the HPI injection exceeds the break flow. Whatever the situation is. So you refill. Now, this is very important.

If you refill very slowly, you're going to mix quite a bit. And I'll show you exactly how. Let's assume for sake of argument that two refills break past, for some reason. The balance is such that they break past.

If you refill pretty fast, the core is going to be so cooled, because you're dumping in there all this cold water. So you're not going to have a resumption of two-phase natural circulation.

You're going to have a resumption of single-phase natural circulation, because this thing is so cool. In order to have a resumption of single-phase natural circulation, the system must fill completely, to the top.

In fact, you also have to intervene and vent the top of the candy cane in order to have this thing to start.

CHAIRMAN WALLIS: Then it spills over the top.

MR. DiMARZO: So that it spills over the top, but you are raising this deborated, you are raising the borated on the other side, and when they get together, this thing can start flowing.

So the deborated is piped, whereas in the back, borated water. Which in a way is true in this state. But if we can do this fast enough, that front could be still pretty sharp.

So, we are advocating a fast transient in the refill mode in order to mix the least amount possible. So we're trying to constrain this. If you refill slowly, you may reach the threshold in the process of refilling.

If you reach separation, you can potentially go into two-phase flow, natural circulation resumption. But as soon as the system starts moving in that mode, you'll throw cold water in the system which will quench everything and stop.

And then the process will repeat itself. So if you want to go slow, the problem you have is that there's an intermittent stop. It's start and stop and start and stop, two or three times. And at that point, once you start moving a slug that way, you'll speed it.

Because every time you chug it up and down, this thing --

CHAIRMAN WALLIS: Now, you've given a word description. Is there some corresponding analytical description and prediction?

MR. DiMARZO: Yes. So this -- At the end of that scenario, once these two steam have met, and you are ready to move the slug in natural circulation, this is where the slug is.

That's all B&W wants to do. Let's examine what we have. The cold leg leading to the cold leg at the bottom of the system, basically, this portion here of the cold leg is kind of mixed, and transitions come by at that time.

This is the steam generator lower plenum. Then the concentration in the lower portion of the tube is very low. Then the center portion of the tube is at this volume. The very front portion of the tube is at this volume.

And then you have the steam generator in the inlet plenum at this volume. And obviously here is the deborated that is coming in from the HPI. So this is the idea on where the slug is when natural circulation decides to resume. Okay?

So, let's note the two things. The first thing that you note is that this front is quite smeared, the way they built it. Our bounding case will be a sharp front, will be top-half distribution.

Second, not all the steam generator is involved totally with deborated, but only a portion of it. So the total volume of a break event deborated is 22.3 as I said. So it's not the maximum possible volume.

So in order to pictorially represent this in the system, I used this way. But basically this dashing means that you don't have full, one hundred percent fresh water. The only region in which you have full, fresh water is probably at the bottom of the steam generator according to that model.

And that is not that cold. But you have a smeared tail, and most important a smeared front, in their model. Now you have seen all these last time, when they use some mixing volume that they have, which I can't speak for their assumption, they get this to be what should be used at the entrance of the core.

Okay? They identify it as Framatome. Two tests were done by David Diamond on that. One to check the neutronics, and one to see what was going to come out of it using this, okay? Using this model.

When I use my ex-vessel mixing model, not accounting for the downcomer mix, which they do, I come with a most severe curve for the same exact slug. As you can see, the volumes under the curves are the same.

So it's the same slug, just the fact that mine is much less mixed than theirs, because I go only to those little valleys. And that is the third calculation that was done last time.

All this re-calculation showed that in as far as the neutronics goes, there is no change, in terms of fuel.

CHAIRMAN WALLIS: So you're saying the Framatome is a measurement?

MR. DiMARZO: No. They did some mixing models that I cannot really understand exactly, but they are -- and I should not report as to how they did that.

CHAIRMAN WALLIS: So neither of those two codes are actually --

MR. DiMARZO: No.

CHAIRMAN WALLIS: Yours is a limiting analysis of making extreme assumptions?

MR. DiMARZO: Of just this coolant. Now, let's move on. Let's now imagine what we could call the worst possible situation. First of all, let's consider how big the slug would be.

And instead of being 22 cubic meters, I can make a slug of 46 cubic meters. That is a slug that fits both slots, all the cold legs, and all the steam generator at that elevation.

More than that, you cannot possibly put in there, because you have no means of storing it there. So that is the largest possible volume that you can store a slug in.

So I took that. That's a bounding case. There's no way you can put more water in there. Second, I took the natural circulation flow rate, a pump that indicates heat, which turns out to be 0.58 meters cubed per second, which is about three times faster than what they do.

That, you will see, is extremely important, because when you push the front tube, it's very important how sharp that front is. So I took the maximum possible low-velocity that I could find.

All right. Then I make two cases. The first is the usual case. It's the case that in principle one could conceive. And then I did a very outlandish case, just to make sure it won't fall in that.

DR. KRESS: And the circulation rate,

that's the amount of steam per second, one percent of the K heat you produce?

MR. DiMARZO: That's right. That's basically what it is. So, formation. The largest slug that I can possibly form is this volume here. There is no other way that I can do more, because here there is an HPI going on.

We are limited, and so this water can essentially flow out of here, overflowing there and swamping the HPI. So there's no way of doing that. On top we cannot go, because there cannot be high, too much, so that's basically capped.

So now, cascade. Now, what do I have to do. I have to fill the system very fast, so that it becomes liquid salt. I want to do that very fast. Let me try to explain to you what the situation is here.

You're going to put more HPI through this location. This HPI can basically plug this side and push this thing up. Correct? So now, you have cold water, colder than this water here, borated water, so there's no question that it's heavy.

It's got more salt in it, and it's cold. It's trying to push ahead warmer water, fresh. So if you don't do that fast enough, they'll mix. Because this is buoyant with respect to the other.

And so they'll inevitably mix. If they mix, they smear my front. And they make this job, leaving you and your drawings, which is more complacent. So I don't want to do that. I want to go fast.

So if I go very fast, I can imagine to retain that front totally un-mixed. The system has to be so cool at that point, it goes without saying. Because I have to go fast.

So I'm pumping in the system a lot of cold water. This has to be a true single-phase natural circulation, so they've got to meet at the top before they are converted and can begin and get the flow going.

If I take that volume and I move it at the top, it will fit all up into the tube of the steam generator. All right? So that is a realistic situation.

At least, you'd have to work very hard to make it happen in reality, but I mean, consider it. You can handle it.

CHAIRMAN WALLIS: Well, actually, it's filling from -- the HPI is filling in both directions.

MR. DiMARZO: Yes, but --

CHAIRMAN WALLIS: So the slug doesn't have to go all the way to the top of the steam generator?

MR. DiMARZO: Yes, because gravity starts -- the two level has to come up at the same level. At the same -- This is a new tube, until you get to the top. You can't have it unbalanced, because how do you hold that --

CHAIRMAN WALLIS: But maybe I'm filling up faster on the reactor side, so it comes over the top.

MR. DiMARZO: You fill from here. It's like you fill a U tube. Doesn't matter where you fill the U tube, the two levels are the same.

CHAIRMAN WALLIS: I see what you mean.

MR. DiMARZO: You have some slight difference in measurements of temperature, okay, but that's all you can get.

CHAIRMAN WALLIS: No voids anywhere. Except at the top.

MR. DiMARZO: No voids anywhere. Except at the top. But you're meant to, condensing. So it's got to go down that way. If I do that, that's called Case A, and I then have to pass the slug through the steam generator of the plenum, where it can mix, and then through two pumps.

The curve that I'm dealing with is this curve here. The solid curve. This curve has about 70 ppm per second dropped. From the initial 3500 ppm, you're dropping at the rate of 70 ppm per second. Keep that number in mind just for reference.

Let me do now an outline the shapes. Just to say that, you know, we don't want to know anything, it's the maximum possible thing. Let's imagine that for some reason, and frankly speaking being experimental it's simple to know how to do this.

You have the front of the slug passing at the beginning in this situation. This cannot be, because inevitably this heavier water will mix with this lighter water.

So I don't really know how to make this happen (1), (2) I don't really know how to make natural circulation happen, because I have a void at the top.

CHAIRMAN WALLIS: But this is extreme, because now it can't mix in the lower plenum of the steam generator?

MR. DiMARZO: Right. But this is more extreme, because I only account for the pump. But realize that I cannot do this. We would be hard-pressed to do the experiment, because you can't do it.

CHAIRMAN WALLIS: But you can still visualize it as an extreme case.

MR. DiMARZO: Very extreme. I would call it outlandish because it doesn't have much of a practicality in actually doing it. I realize it's an experiment.

CHAIRMAN WALLIS: But it's very useful to have a limiting case.

MR. DiMARZO: Exactly. So that case is Case A -- is Case B. We go from 70 ppm per second to 150 ppm per second dropping in that so-called experiment of the mind. All right?

Both these experiments, the natural circulation would be handled by Dave Diamond in the forum for circulation. Now let's switch gear. And let's say, what about if I pump?

If you pump, you have a tremendous degree of freedom. Because you can pump any time you want. You can go there, switch this thing on, any time you decide. So there is no limitation on where the slug should be at that point.

The worst possible case is if the slug is somewhere before the pump, so that the front goes only to the pump, and the tail goes to the back. That's the case we're going to examine.

We're going to take a very benign pump. The slug bottom is only 28 meters cubed, as opposed to

46 meters cubed, which is the maximum. So it's a very small -- it's a rather small slug.

CHAIRMAN WALLIS: Why is it smaller?

MR. DiMARZO: Just making the schedule, see we are already in trouble right there. So I'm just picking a case.

CHAIRMAN WALLIS: Oh no, it's got to be small for a reason.

DR. KRESS: Well if it already gives you a problem, why worry about a bigger one?

MR. DiMARZO: I'm just trying to show you a case, and I am showing you that we really are in trouble right there. So pumping is out of the question. If you want to make a bigger slug --

CHAIRMAN WALLIS: Okay, so if it were 46 it would be worse.

MR. DiMARZO: Exactly.

CHAIRMAN WALLIS: I thought you were going to show us you didn't have a problem.

MR. DiMARZO: No, it's not going to happen like that. The second thing I'm doing is I'm already trying -- identifying that there's a slug stuck in the pump.

And I'm saying, when everything is said and done, the speed to which all the slug goes through the vessel is past the steady straight speed for the pump. This is absolutely no concern. Very, very benign. It'll go much faster than that.

Okay? Now in spite of all this, I mean with all these modifications, I still have to account for one thing, that when I --

CHAIRMAN WALLIS: So the reality might well be worse --

MR. DiMARZO: Worse. There is no problem making it worse, okay? But when you start the pump, you draw water from the other leg. There is an inter-leg circulation that you have to account for.

Now, I'm making the assumption that what's drawn from this leg and mixed with this leg is totally borated. That's also non-conservative, because in the reality it will draw from the discharge of the first leg.

So it should be a little less borated than what you think. So that's another mitigating assumption. So at the end of the day I come up with this.

We are dealing now with 1500 ppm per second drop. One order of magnitude larger than the worst conceivable case in natural circulation. And this is not extreme at all. It's very, very benign.

But that gives you an idea of what type of a drop you can afford before getting into trouble. So now I give it to David Diamond, who's going to give you the consequences that you've done some fuel damage in your pumps.

So Case A is, again, the maximum slug at the maximum flow rate with the reasonable assumption as to where it is and how it moves. The second Case B is that, what I call, outlandish case, because it's kind of a figment of my imagination worst case.

And then the last case is going to be the pump case.

CHAIRMAN WALLIS: But the pump case, whereas in the previous case you said you're making some extreme assumptions, in the pump case --

MR. DiMARZO: Very benign.

CHAIRMAN WALLIS: You're doing benign, so you would change your philosophy a bit.

MR. DiMARZO: I could make it much worse. Doesn't change the ends. If it's worse and it works, it still works.

CHAIRMAN WALLIS: And the only time that it had any experiment versus observation was a very early University of Maryland experiment.

MR. DiMARZO: When they did the vessel.

Now, to make do, we tried to do additional experiments. We used your facility to have a blind check of that model.

Unfortunately, year 1000 came in that process, and basically the facility was not available anymore to do that thing. We can go back and do more of that, but then --

CHAIRMAN WALLIS: Why don't they just run RELAP or something like that and see what it predicts?

DR. KRESS: No, we wouldn't --

CHAIRMAN WALLIS: Why not?

DR. KRESS: RELAP doesn't know how to mix it.

CHAIRMAN WALLIS: Well, RELAP is relied upon for other situations. I mean, it's so bad that it's hopeless for this purpose?

DR. KRESS: RELAP is --

MR. SCOTT: There's paper in the literature that Kent State did for Westinghouse AP600 plant, and they found that they had to use a so-called high order salute tracking model, which RELAP doesn't have, so --

MR. DiMARZO: It's as if you have to replace, so it's a --

CHAIRMAN WALLIS: RELAP does track boron, doesn't it?

MR. SCOTT: Yes it does, but this is moving beyond a couple of meters. Anyway, David.

MR. DiMARZO: And then I'll come back up for the conclusion.

CHAIRMAN WALLIS: It gives me a little bit of an uneasy feeling. I mean, you have to develop your own ad hoc analyses for this because there's no code which is capable of doing it.

Is that right?

MR. DIAMOND: You need a turbulence model to answer that mixing, which RELAP doesn't have.

CHAIRMAN WALLIS: Well the CFD you did charge it and agree with experiments before --

MR. DiMARZO: No, the CFD was about the vessel.

CHAIRMAN WALLIS: I know, but, well you did try --

MR. DiMARZO: We could do a CFD about the pipes, that's okay. We didn't do that.

CHAIRMAN WALLIS: Well, if it didn't agree with the vessel, why would it be useful?

MR. DiMARZO: The point is when somebody's simple model worked --

CHAIRMAN WALLIS: So we should maybe throw away covers and do simple models every time?

DR. KRESS: Well, there's a lot to be said for that.

MR. DIAMOND: Another key player in that type of work is Jose Narnbauch, who just got up and walked out. But he developed the remix code, which is a special application code for trees.

CHAIRMAN WALLIS: This is the field --

DR. KRESS: That goes a way back, yes.

MR. DIAMOND: Yes.

DR. KRESS: That goes way back.

MR. DIAMOND: Yes. Anyway, before I answer -- or before I continue along the same lines as Marino was starting on, and show you the results using those new curves that Marino has generated.

Let me go back to the presentation that I made in June, and let me show the last slide from that presentation so you remember a little bit about what I was talking about at that time.

I had showed some comparisons of our calculations, which are based on a PARCS/RELAPS model, so it's a three-dimensional neutronics model. And I had showed those in comparison with the B&W Owners' Group calculations, which were a point model.

And we saw that the 3-D analysis gives a lower imaging deposition relative to point kinetics.

We also showed that the evolution of the energy deposition for the boron dilution event is much slower than the rod ejection accident, which is the design basis reactivity accident.

And what we discussed also is the fact that thermal hydraulic feedback limits the fuel enthalpy during the boron dilution accident, and that was for the cases that we looked at at that time, which were the natural circulation cases with the original curves that Marino had generated.

In those cases, the initial enthalpy increase was the less than twenty-five calories per gram, which is rather small in terms of fuel damage. We saw a void formation during those events.

It was sporadic. D&B might be possible in more severe cases, and you'll see that a little bit more in the cases that I'm going to show. We also noted that we have made comparisons with a completely independent code package.

Independent in the neutronics aspects, and that's the BARS/RELAP five code, and the comparisons I claimed were good, although I didn't show any.

CHAIRMAN WALLIS: Just a second, how did you get to this point?

MR. DIAMOND: RELAP is no good for the

mixing analysis. Where we used RELAP is just for the simple boron transport and the thermal hydraulic conditions in the core after the restart of the natural circulation or pump.

The questions that had arisen earlier, where we mentioned that we could think about refinements, where extensions of the analysis had to do with mixing in the core.

The core is represented as a series of parallel channels with no mixing, and obviously PWRs have mixing. We assumed that the boron concentration was uniform over the radial direction in the core initially, at least at the core inlet.

And of course, there may be radial or azimuthal non-uniformities because we're only talking about one loop being impacted and therefore the slug is coming in from one side.

And we noted at that time that we had not turned on the pump in our calculations, that these were natural circulations. So that was where we had gotten to last time, and the material that I spoke about last time is included in the hand-out that you have today.

So, if you think of something that, "Gee, Diamond said that last time," it's in that hand-out and you can check on that. And that also has my slides, which discuss the methodology that we use, and the reactor model.

And I'm not going to repeat that information I'm going to get right to the results.

MR. SCOTT: It's in the second hand-out? You have two --

MR. DIAMOND: One is dated June 26, and one is dated today, it's called Part Two.

CHAIRMAN WALLIS: Part Two has no date on it.

MR. DIAMOND: September 9 is the date on it.

CHAIRMAN WALLIS: What's Part Three going to show us?

MR. DIAMOND: All right. So the calculations that we're going to talk about today, the first calculation is the start of the single pump with the dilution as explained by Marino just a little bit earlier.

And what that is going to show is a very fast reactivity insertion relative to natural circulation. And then the two natural circulation cases that I'm going to show, those don't show as a slower insertion, but it's a larger reactivity insertion relative to the previous case that I explained.

And that's because in this case the boron concentration goes all the way down to about zero ppm; in the previous case we only went down to about 250 ppm.

CHAIRMAN WALLIS: So your conclusions have changed since the last meeting we had? The last meeting seemed to be reassuring, but not much energy was deposited in the fuel.

MR. DIAMOND: That's correct.

CHAIRMAN WALLIS: Since then, after some prodding, it says, "Well, what we've done after the ACR Subcommittee meeting." He must have redid his calculations or looked at some more limiting cases and then you analyzed them, and now the story is all different from what it was.

MR. DIAMOND: The story really isn't very different.

CHAIRMAN WALLIS: It's not --

MR. DiMARZO: Let me -- It was not that we only did the calculations with the conditions more severe. So it's a conclusion where I did more severe cases. At that point we did connect.

MR. DIAMOND: But we had discussed these

cases last time, and I think that everything that we said last time was just confirmed by these calculations.

So I don't think that our conclusions have changed, but I think we have more information now to base those conclusions on. So first I will show the results from the natural circulation curves.

These are the curves that Marino just showed. I want to point out that the time, our time starts at 100 seconds. This is actually after hours into the small break LOCA for the purpose of the calculations that I'm about to show you today.

The boron dilution starts at 100 seconds, and as you see, Curve A takes about 75 seconds, Curve B about 50 seconds, to go from 2500 down to about zero ppm.

DR. KRESS: Do these calculations prove your build-up of xenon in the core?

MR. DIAMOND: You mean prior to the --

DR. KRESS: Prior to the injection.

MR. DIAMOND: No, they do not.

DR. KRESS: So that's a conservative.

MR. DIAMOND: Yes. It would --

CHAIRMAN WALLIS: How much is that xenon worth in terms of reactivity?

DR. KRESS: He said it was hours, that's quite a bit.

MR. DIAMOND: Yes, there is a lot of xenon that does build up, and that tends to poison the core more.

CHAIRMAN WALLIS: That's been ignored here?

MR. DIAMOND: Yes. Well, this is based on just having the equilibrium xenon remain as constant.

CHAIRMAN WALLIS: But that's not realistic, is it?

MR. DIAMOND: Yes, there is build-up of xenon, which tends to reduce the reactivity in the core. That's true.

CHAIRMAN WALLIS: Well, would it make any difference to your conclusion?

MR. DIAMOND: No, I don't think it would, and I think that what's important here is that, not only do you have the build-up of xenon, but you also have the insertion of all of the control rods in the core.

So you have many, many dollars of negative reactivity at the core.

CHAIRMAN WALLIS: The surprising thing is you need the boron. In other words, the control rods alone won't do it in the start-up cycle.

MR. DIAMOND: You mean to shut down?

CHAIRMAN WALLIS: Yes.

MR. DIAMOND: But you do have the boron. I mean, the HPI has been on. You've got 2500 ppm of boron in the core.

CHAIRMAN WALLIS: We're really worried about boron dilution, and designs of the control rods alone shutting down.

MR. DIAMOND: Yes, but --

DR. KRESS: That point was made in the report originally, when you made the cycle, and even with this dilution coming in, you're still checking.

CHAIRMAN WALLIS: And it's a longer period for the Westinghouse reactors.

MR. DIAMOND: Yes. Right, sure, in an endless cycle you don't have boron in there, so it's -- Yes, so the first curve I wanted to show was power versus time, and it happens to be for the Curve A -- I'm sorry, this is actually a Curve B scenario.

One that takes place in about 50 seconds, where dilution takes place in about 50 seconds. I just wanted to first point out that --

DR. KRESS: It's mislabeled there?

MR. DIAMOND: I'm sorry? It's mislabeled? Yes.

CHAIRMAN WALLIS: It should be B?

MR. DIAMOND: It should be B. That's the faster line. You're starting out here from about 10^{-6} percent power, and quite a bit shut down. This accident has been going on for a long time, and the reactor is shut down.

Btu then, because of the boron dilution, it comes all the way up quite a few orders of magnitude to above 100 percent of rate of power. And I'll show the --

CHAIRMAN WALLIS: Next curve shows six times rate of power?

MR. DIAMOND: Yes.

CHAIRMAN WALLIS: Sounds like a dramatic event.

MR. DIAMOND: This shows the result on a linear scale for both Curve A and Curve B. And the only difference really, or the most significant difference that I see, is the fact that the Curve B occurs faster.

That's the one that's at a somewhat faster rate than Curve A. But essentially what you see is that, with the exception of a number of spikes above 100 percent, the power is going up and down in the range between zero and 100 percent, until such time as the boron slug has moved out of the core, and the core has shut down again.

CHAIRMAN WALLIS: Now the implication -- Sorry.

DR. KRESS: Excuse me. What causes the spikes?

MR. DIAMOND: Well, the spikes -- I'll show you what causes the spikes. The spikes are caused by the interaction of all the different reactivity effects.

DR. KRESS: But those are feedback spikes.

MR. DIAMOND: Yes, exactly. This is the same plot, only the time-scale is reduced so that it's spread out and you can see the shape of these spikes. And as I say, some of them are quite sharp and the others are really not too sharp, on the order of seconds.

I should say the width of them is --

CHAIRMAN WALLIS: The marks are at A and B, and the sort of idea was that the conditions would be somewhere in between the two, or are these two extreme cases, or?

MR. DiMARZO: A is extreme. B is outlandish. In other words B is something I can imagine doing.

CHAIRMAN WALLIS: Yes, but then with all these --

MR. DiMARZO: B is a figment of my imagination.

CHAIRMAN WALLIS: But with all these oscillations and large power bursts and -- I just wonder if someone else couldn't dream up a Curve C, which was no more outlandish than yours, which gave more dramatic power bursts.

MR. DIAMOND: Well, the pump on will look a little different.

CHAIRMAN WALLIS: Yes.

MR. DIAMOND: But the point is that from the neutronic response, there's not much of a difference between Curve A and Curve B.

CHAIRMAN WALLIS: Just one's larger than the other.

MR. DIAMOND: Right.

CHAIRMAN WALLIS: The peak is different.

MR. DIAMOND: From the point of view of developing those two curves, the thinking was quite different, but the results are very similar. Now in order to explain these results, you do have to look at the component reactivities.

And this shows the boron reactivity and

the total reactivity. The boron reactivity -- again, we're starting from 100 seconds -- it goes up to about ten dollar addition.

So it is certainly a significant amount of reactivity that's being added. Just like in a boiling water reactor, when you go from full power, and we have 40 percent void fraction to low power, zero percent void fraction, there's a large reactivity display.

All right. I'll probably shouldn't have said. It will confuse the issue. But the thing is that the total reactivity, the thing that is driving the global power during this event is very small.

It just goes above a dollar over here, and then it oscillates quite a bit. And it's causing all of those power spikes that we saw initially. And of course, the reason that the total is low, and the reason that it is erratic, is because of the fuel temperature, and especially the moderator feedback.

CHAIRMAN WALLIS: Does the void fraction make any difference? Are you making voids in this?

MR. DIAMOND: Yes. And that's exactly why you get these spikes here. This is due to the creation and collapse of voids throughout the core.

CHAIRMAN WALLIS: So it shuts itself down?

MR. DIAMOND: That's correct.

CHAIRMAN WALLIS: That goes then to the other interpretation which I think is incorrect, which would be that since a tiny bit of reactivity gives you these spikes, if you are certain about this reactivity you can get much bigger spikes.

But the reason -- the knowledgeable way to reason is if we did get more reactivity, it would shut itself down in voids, isn't it?

MR. DIAMOND: Yes. You've hit upon a very important point here, and that is that the inherent characteristic of these water reactors, low enriched water reactors, is that they have a large fuel temperature and moderator temperature feedback.

Now --

CHAIRMAN WALLIS: And voids, the voids are not there.

MR. DIAMOND: Yes, and when I say moderator feedback --

CHAIRMAN WALLIS: Oh, voids are in there?

MR. DIAMOND: Yes. I mean, posted density and temperature effect. So it's the competition between the feedback and the boron which causes the power to spike like that.

And if we then look, we focus in on the

fuel rod, and we look at the pellet-average fuel enthalpy throughout the reactor as a function of time. And we look at the place in the reactor where that fuel enthalpy is at its peak, then we get this curve here.

And again, there's not too much of a difference between Case A and Case B. There's an initial rise -- this initial rise caused by that initial power spike. And a little plateau here, and then eventually a value which is the peak value.

And a bunch of oscillations as you get peak transfer.

CHAIRMAN WALLIS: This is different from the 37 or whatever it was we had last time.

MR. DIAMOND: Actually, it's similar. And let me take the same curve and let's zoom in on it and look at the first 20 second period, from 120 to 140 seconds.

So this is the exact same curves, the same quantity that I just showed. It's the peak pellet-average fuel enthalpy. And if we look -- Well, let's look at this one first, Curve B.

The initial enthalpy rise is only about 15 calories per gram. And then the enthalpy rise is much slower, and maybe there's a total of -- when you reach this plateau, maybe it's 25, 30 calories per gram.

The point is that if you're worried about rapid energy deposition, you're really worried about this region here. And that enthalpy rise is really not significant.

Now, what happens eventually is that you get up to about 100 calories per gram. That's the maximum enthalpy rise. But even at that level, even if it occurred rapidly -- Well, at that level, you wouldn't be worried about fuel grams as yet.

But anyway, the point is that this is occurring only after a very long period of time. This is at 132 seconds. So I think what's most significant is this initial increase, which isn't much different than what I described using the original core and dilution curves that we had for the last meeting.

Now, and I'll show the difference in the pump-start case in a minute, but I also wanted to show void fraction, because --

CHAIRMAN WALLIS: Well, I think for the record I'd like to report that our member Victor Ransom has joined us.

DR. RANSOM: Sorry for being late.

CHAIRMAN WALLIS: Excuse me.

MR. SCOTT: Let me say something. If the

100 calories per gram, because that takes several seconds to get there, would not be the same as these reactivity transients that go to 100.

MR. DIAMOND: That's correct.

MR. SCOTT: And take 20, 30 milliseconds. So we might not get the damage, even in high burn-up fuel.

MR. DIAMOND: Well, the point is the damage at that point might be acceptable, kind of, fuel damage, and not damage that would be associated with fuel fragmentation or dispersal.

This is a curve of the maximum void fraction, looking at the void fraction at all of the positions within the core at which the calculation was carried out, with RELAP, I should add.

And of course this is the locus of many individual positions that have high void fraction, and one such position here at the bottom of the core, at a particular thermal hydraulic channel is shown here, in order to show that the void fraction at any given location doesn't stay up at 80 percent.

It's really growing and collapsing sporadically. So you have this chugging situation, so to speak.

CHAIRMAN WALLIS: Whereabouts in that

picture is the maximum fuel pellet enthalpy? This is Curve A?

MR. DIAMOND: Yes, this is Curve A, which was later than 132.

CHAIRMAN WALLIS: Oh, it's about 145 or something?

MR. DIAMOND: Okay, so I guess that was at this point here.

CHAIRMAN WALLIS: So it's in there.

MR. DIAMOND: Yes, and then things kick through.

CHAIRMAN WALLIS: So after that, do we care much? What if there's another peak later on?

MR. DIAMOND: Well, we don't even care about --

CHAIRMAN WALLIS: There's another peak later on it kind of follows that.

MR. DIAMOND: We don't even care about this. I mean, don't forget, this core has been boiling for hours. So the fact that you're getting some void fraction here seems to me --

CHAIRMAN WALLIS: But DiMarzo actually chilled it with his cold water coming rushing in.

MR. DIAMOND: Well, it's true that the water here -- we're at low, much lower pressure and temperature when this boiling takes place. The conditions here are supposed to be on the order of six mega-pascals, and about 400 --

CHAIRMAN WALLIS: Yes, what I was observing was that these peaks in void fraction, the one around 145 and then the rise up to 160, those track pretty well the rapid rise in fuel enthalpy as well.

So what's happening is it's heating up, and very rapidly, soon after that it makes voids.

MR. DIAMOND: Yes.

CHAIRMAN WALLIS: So the voids track the power.

MR. DIAMOND: Well, yes, except the thing about voids too is that they transport up the channel as well. So it's complicated by the transport and the generation.

CHAIRMAN WALLIS: Yes, but in the initial sudden surge of energy, they aren't cooled much in that period.

MR. DIAMOND: No, not in the initial stage. So, my results from these cases are listed here. The first is that it's important to remember that the total reactivity addition is always much less than the driving factor, which is the boron dilution. That's important.

The fuel and moderator reactivity feedback are very important. And the PWR, also in the PWR. The initial increase in the peak fuel enthalpy -- and by "initial increase" I'm talking about in the first second -- is about 15 to 25 calories per gram.

From the point of view of fuel damage is not inconsequential. The peak fuel enthalpy during the entire transient is in the range of 90 to 100 calories per gram.

And again, though, that peak fuel enthalpy occurs slowly and therefore we're not talking about catastrophic fuel damage here. The void fraction is high enough to expect DNB.

But if so, it would not be different than during the earlier portion.

CHAIRMAN WALLIS: Wouldn't that change the peak fuel enthalpy, the DNB?

MR. DIAMOND: Yes. You mean because of the heat transfer? Yes, one feeds back on the other. But that's taken into account in --

CHAIRMAN WALLIS: In RELAP?

MR. DIAMOND: In the guidelines, yes.

CHAIRMAN WALLIS: So does the code predict DNB?

MR. DIAMOND: The code will predict what

heat transfer pictured, yes.

CHAIRMAN WALLIS: Does it predict DNB for this case?

MR. DIAMOND: Oh, does it predict it for this case? Well, then you have to monitor the DNB ratio, and we did not monitor that.

CHAIRMAN WALLIS: So you say high enough to expect, and a curious person would ask, "Well, did you get it?"

MR. DIAMOND: Yes. Okay.

CHAIRMAN WALLIS: You're tantalizing us, because we don't know whether you got it or not.

MR. DIAMOND: Yes, and I'm sorry, but I don't have that.

CHAIRMAN WALLIS: Maybe by later in the week you can tell us.

DR. FORD: Could I ask a question?

MR. DIAMOND: Certainly.

DR. FORD: You essentially come out with a correlation between the measured peak fuel enthalpy and the calculated rate of boron loss during the transient. Is that correct?

The rate of boron loss from the University of Maryland calculations are not calibrated into the data. Is that correct? So are we intentionally in a situation where we're just scaring ourselves, because we don't have a calibrated rate of boron loss that's calculated -- calibrated.

MR. DIAMOND: Yes, that's correct. That's correct and that's why it seems like we keep going to more and more extreme cases, and, to wit, I'm going to show you the next extreme case, which has the pump coming out.

DR. FORD: I'm sorry to jump ahead of you. You're right, so as far as the rate of boron loss the high fuel enthalpy.

MR. DIAMOND: Yes.

DR. FORD: So does that not tell us communally that the big urgency to calibrate are verified by thermal hydraulic calculations.

MR. DIAMOND: Unless you're satisfied by all the circumstantial evidence which keeps showing that you have to keep pushing your assumptions to more and more conservative values to get to that point where you're rate of dilution is high enough.

I mean, my personal opinion is that we keep pushing. The licensee said one thing, and we pushed way beyond that and we're still having trouble getting to a severe accident.

And in the next case we'll get closer, but at the cost of going to lower and lower probability.

DR. FORD: But you go to higher and higher burn-up fuels? Doesn't the urgency become that much greater?

MR. DIAMOND: Well, when we look at this, or at least when I look at this, I'm looking at it in terms of what we'd expect those limits to be for high burn-up fuel.

CHAIRMAN WALLIS: Well, I think when we looked at actual data for high burn-up fuel, there's very little of it. And it was not that conclusive that you could draw a line and say above 100 K, because you weren't always.

MR. DIAMOND: Right.

CHAIRMAN WALLIS: And so there's some uncertainty there. What you seem to be saying is that you cannot rule out the kind of energy deposition which could give you a column with high burn-up fuel.

MR. DIAMOND: No, no. I don't seem to be saying that, I am saying that.

CHAIRMAN WALLIS: You are, you have said that.

MR. DIAMOND: Or no, I will say that in the next two minutes when I show the pump start case.

CHAIRMAN WALLIS: You are about to say it.

Isn't that true here too? Isn't 100 calories per gram, is not -- doesn't rule out damage to high burn-up fuel, does it?

MR. DIAMOND: No. At this rate of addition, I think not, no. I don't think that --

CHAIRMAN WALLIS: Are there some criteria which say rate of addition and tell the deposition under the LOCAs of acceptable conditions or something?

MR. DIAMOND: In my mind, there is.

CHAIRMAN WALLIS: Your mind?

MR. DIAMOND: Yes. I would defer to fuel behavior experts, but this type of energy deposition is of concern when there's no opportunity for the CLAD to come to equilibrium with the pellet.

It's a sudden jolt to the CLAD. And in this case it's not a sudden jolt, it's happening over 90 seconds, and therefore -- However, the definitive answer to that ought to come from the fuel behavior person.

MR. SCOTT: But David, I think when you enter the next set too, but go back to this one. You have channels that have high burn-up fuel, and channels that have medium burn-up fuel.

And are not these high 90 calories per gram one of the low burn-up fuel?

MR. DIAMOND: Yes. No. Yes, this is for the low burn-up fuel, right. That happens to be -- the particular design that we're looking at, the B&W, they had put their control rods in the higher burn-up fuel, and therefore, since as I say, all the control rods are inserted in this particular case, the high burn-up assemblies don't have the high power because that's where the control rods are.

And the low burn-up assemblies are the ones that are getting all the high fuel energy deposition and high void fractions, etcetera. Okay. So now let's take a look at the pump restart case.

Again, this is the curve that Marino showed earlier. And I've just plotted it here against the case from last time. And you can see that the -- And again, we're starting at 100 seconds.

The boron event is over on the order of 20 seconds.

CHAIRMAN WALLIS: What's this 25 percent figure?

MR. DIAMOND: That is the pump rate based on the analysis that Marino did. Where he non-conservatively assumed that there was a ramp-up of the pump rate, so that we were looking at a fractional pump rate, rather than complete insertion.

I'm sorry, complete, 100 percent flow.

MR. DiMARZO: Yes. The reason why I put it much higher. It's much worse.

CHAIRMAN WALLIS: It's worse? So why did you choose the 25 percent, it seems somewhat arbitrary.

MR. DiMARZO: I just picked a case which seemed to perform better with the insertion. So I said this percent has nothing wrong. So it was by all means a non-conservative estimate. And when Igor comes to me and says we are really in trouble there, we could push it worse, but the answer wouldn't change.

We would still have --

CHAIRMAN WALLIS: See, that's what I found real trouble with. Because your A and B curves, these are outlandish, extreme cases. Now when you're looking at the bump pump, you say, "Well, I will not look at the extreme case. I'll look at a 25 percent," when it could be 100.

So you're telling a somewhat different story. That's going to -- Someone's got a cost to whoever's evaluating.

MR. DiMARZO: Yes, but there are two stories. One story is natural circulation. We want to tell you that no matter what you do with natural circulation we have no problem.

So we went and forced the RCP on in order to make that case. On the pump, as soon as we start with something close to the --

CHAIRMAN WALLIS: You run into real trouble.

MR. DiMARZO: Immediately we are in trouble.

CHAIRMAN WALLIS: So you burn up the pump.

MR. DiMARZO: So there is no point in going into extreme.

CHAIRMAN WALLIS: I see.

MR. DiMARZO: We are only throwing our hands up in the air like this.

CHAIRMAN WALLIS: So that needs to get across to the audience.

DR. KRESS: What is 25 percent, like one pump starting?

MR. DiMARZO: No, no, it's a quarter of one.

MR. SCOTT: Remember, the pump is off, and it has to start. Well, we've only got, like, 20 seconds? It can't possibly get up to very high speed in 20 seconds.

MR. DiMARZO: We don't look towards that

kind of a range, but the program is the fluid isn't going to pump.

CHAIRMAN WALLIS: But you don't know how fast it starts? Why don't you put in what it really does?

MR. DiMARZO: I don't know what the fluid does. You know, you have fluid in the whole room. The pump will go up to speed in 20 seconds. That doesn't say that the fluid --

CHAIRMAN WALLIS: I would think the fluid was pumped pretty quickly. Oh you mean a momentum equation has to be used? We found a case, Dana, where the momentum equation matters? When you bump the pump, how rapidly you speed up the fluid.

DR. POWERS: Understand, I come from being trained by Ivan Patton. There was the Big Bang, and everything else was the momentum equation.

MR. DIAMOND: All right, well this shows the resulting power on a logarithmic scale, similar to the results that I showed earlier. Except that now everything's happening in about 20 seconds.

And this is the boron dilution curve that I just showed, and this is the power which comes up to, well, quite a bit higher than 100 percent power, but duration is much shorter.

CHAIRMAN WALLIS: It looks like something over -- It looks like 2000 percent or something.

MR. DIAMOND: Well, we'll take a look.

CHAIRMAN WALLIS: You're going to show us.

MR. DIAMOND: Well, actually, this doesn't go all the way to the --

CHAIRMAN WALLIS: What is it?

MR. DIAMOND: I'm not sure, maybe you're right. It could -- maybe it is 2000. The thing is, I never look at these, because I don't find them to be interesting.

What's really important is the integral, the energy that --

CHAIRMAN WALLIS: But it's still dramatic, and someone, a member of the public who wanted to make a point could say, "Look, it's 20 times."

MR. DIAMOND: Yes, right, so, okay, you're right, this keeps going up here. But I wanted to show -- zoom in and show you what the oscillations look like.

And here there's only a few oscillations because this is the boron dilution and you're already coming back up to high boron concentration. As the slug exits through the core.

CHAIRMAN WALLIS: So you're at 100 percent power or over?

MR. DIAMOND: Yes.

CHAIRMAN WALLIS: So quite a few seconds.

MR. DIAMOND: That's right. In this case, remember before I pointed out that you were really -- most of the time you were between zero and 100 percent power, with a couple of occasional spikes.

But here, the significant energy being deposited, it's above 100 percent nominal. So we do have a different situation with the pump start. And if we look at again the local pellet average enthalpy, the general behavior is similar.

That is, we have an initial jump and then it continues to rise, plateau-ing at several -- well, not even a plateau at several points.

DR. KRESS: That's still cooling off a little bit, by the fluid? It's not much cooling. Because that's almost the strength --

MR. DIAMOND: That's right. It's partially -- The cooling of the fuel is one effect. The different power spikes is another effect. Don't forget now that I'm showing something that is the conglomerate.

So you have spatially dependent behavior. I'm showing the peak value.

DR. POWERS: Can you give us some idea of where this is happening?

MR. DIAMOND: Yes, this is happening in the bottom of the core, because it's the bottom of the core that sees that slug first. It's the bottom of the core that's responsible for that initial power spike.

And it's happening in the low burn-up fuel. Because as I explained it's the low burn-up fuel -- I'll show this in a little bit. It's the low burn-up fuel that does not have a control rod in it.

CHAIRMAN WALLIS: And you chose not to run the pump at 100 percent or anything like -- Did you have runs for other assumptions, like 100 percent pump?

MR. DIAMOND: This is difficult enough as it is. You start to get into conditions like that, you're really pushing all of the models and the code.

CHAIRMAN WALLIS: So you have difficulty predicting.

MR. DIAMOND: Yes. Well, after a certain point. I mean, we were able to do this calculation, but each time you do a calculation like this you realize that you're starting to get into regions which the codes were not designed to account for.

CHAIRMAN WALLIS: Which means there's

uncertainty in the numbers, if they are much bigger or smaller.

DR. POWERS: You would have --

MR. DIAMOND: There is uncertainty.

DR. POWERS: Do you have a way of getting through that says we have a code that allows us to read these things, we can. This calculation, although somewhat in the other calculations, routinely you would need a code that has these capabilities?

MR. DIAMOND: No, I don't have that written up anywhere.

DR. POWERS: Surely you could use it.

MR. DIAMOND: Yes, well there are all sorts of things -- Well, I mean, for example, here you get the centerline melting. The consistency laws in relation in RELAP could be such that it would get up to the melting point and continue to be able to calculate in an orderly fashion rather than getting some block.

That's one example.

DR. POWERS: You don't calculate centerline vapor pressures?

MR. DIAMOND: No. But I'll show you when we do get up to centerline melting, and that's already pushing --

DR. POWERS: You show centerline temperatures at 3000 degrees Centigrade, and if you include vapor pressure at different points, it's --

MR. DIAMOND: Right. Okay, I'm just taking the same fuel enthalpy curve, and again blowing up the time scale, so that we're only looking at four seconds here.

And the point is that I wanted to first show this initial rise here is now on the order of 30 calories per gram and fractions of a second. If we're looking at maybe one second, then we're talking about maybe 60 calories per gram increase.

So now we're starting to talk about getting a considerable amount of energy deposition, in a small amount of time. Forgetting about the fact that this is going up to very high fuel enthalpies, which are not going to lead to minor fuel damage, but may lead to major fuel damage.

So that's the blow-up here. And this eventual fuel enthalpy was about 180 calories per gram. If instead of looking at the pellet-average enthalpy, we focus on the fuel centerline.

And instead of talking about enthalpy it's more convenient to talk about fuel temperature. So this shows the same shaped curve as for the pellet-average enthalpy, but now we're talking about the fuel centerline.

DR. POWERS: What's the burn-up on this?

MR. DIAMOND: It's very low. It's --

DR. POWERS: Very low as in 4 gigawatt gauged --

MR. DIAMOND: No. As in less than that. Yes. Essentially zero.

DR. POWERS: So essentially, it actually occurs more, given that greater number.

MR. DIAMOND: Oh, okay.

DR. POWERS: I mean, you're just basically I think it was --

CHAIRMAN WALLIS: But there may be some other fuel which is only up to 2000 which has a higher burn-up.

MR. DIAMOND: Yes.

CHAIRMAN WALLIS: Which is a whole lot of different --

MR. DIAMOND: That's right. Don't forget, I said that the only reason that the highest, most of your conditions are occurring in low burn-up rather than in high burn-up fuel is that in the BNW fuel-management scheme, the control rods are in the high burn-up assemblies.

Now if we were looking at a different fuel-management scheme, then, where they placed the high burn-up fuel assembly next to a low burn-up fuel assembly, and one was being driven by the other, then this could take place in a high burn-up fuel assembly.

But the conclusions that we want to reach are independent of burn-up. Okay, so this shows the peak fuel centerline temperature. That is, the peak throughout the core. And it occurs at about 113 seconds.

And if we just focus on 113 seconds and look at the centerline temperature throughout the core. This is -- as a function of axial position, this shows you a couple of things.

One, it shows you how things are happening at the bottom of the core. This is the bottom of the core, this is the top of the core.

CHAIRMAN WALLIS: Tell me about the nodes, your calculation on nodes there.

MR. DIAMOND: These, yes, these different curves represent different fuel assemblies.

CHAIRMAN WALLIS: But these are combined -- the nodes, the discretization is your numerical method?

MR. DIAMOND: Yes.

CHAIRMAN WALLIS: So we have very steep ramp on the left. And we wouldn't really know what the clusters would do if you had to find the nodes right at the left. You might have a different maximum is what I'm saying.

MR. DIAMOND: Yes.

CHAIRMAN WALLIS: If you had primary nodes.

MR. DIAMOND: Right. And now, if we just look, though, at this second node here, and we look at all these points and how they're distributed through the radial section of the core.

This is a 1a portion of the core. By the way, I apologize, this was supposed to be in living color. And due to technological difficulties --

CHAIRMAN WALLIS: Well, lots of these are pretty darn high.

DR. POWERS: I'm much more concerned --

MR. DIAMOND: Okay. Well, so we can look. Now this is the center of the core. This is the periphery out here. And here's where you can see the -- let's see, these are channels.

Okay, these are low burn-up assemblies along this diagonal. Don't forget now, every other assembly has a control rod. So there's a control rod here, there's one here, one here, one here, one here,

here, here, here, surrounding the --

DR. POWERS: Well, we're more concerned about the higher burn-up fuel than I am the pressure --

MR. DIAMOND: Yes, and I'm glad you noted that, because here I am talking about the low burn-up assemblies are experiencing the higher centerline temperatures. In reality, this is not much different.

And this is a high burn-up.

DR. POWERS: So where are you getting 100 --

MR. DIAMOND: Yes. Right. So, I don't know where you want to draw the line in terms of acceptance, but as an exercise I drew that line at 3000 Kelvin.

And I said, okay, that's unacceptable fuel damage above that. And what it represents in this case is 20 percent of the fuel assemblies. In other words, 20 percent of the fuel assemblies would reach 3000 Kelvin.

CHAIRMAN WALLIS: And this is only for a 25 percent pump.

MR. DIAMOND: Yes.

DR. POWERS: So there's no burn-up --

CHAIRMAN WALLIS: That's why it would be

helpful if you made a few other assumptions, like 50 percent pump, or something different just as a comparison. Because this -- It just seems it's sort of an arbitrary number.

DR. POWERS: Why are you looking at the pump bump at all. I think they already know that the pump bump is --

CHAIRMAN WALLIS: Okay, so you're going to say --

DR. POWERS: Well, this is true. The thing is you can put all the rules you want to on bump pump. There's going to be an unbelievable driving force on that pump.

DR. KRESS: All we've got is procedures that say don't bump the pump. That bothers me.

DR. RANSOM: Well, it's no worse than saying shut off the HPI and that will open. You can do that. You get in trouble like Three Mile Island. The other thing.

I'm sorry I missed the earlier part of this presentation, but I have trouble with the boundary conditions that are used in this analysis, and also the one that DiMarzo was using in his mixing analysis.

Because they leave off the vent valves.

Now, unless you do a nanometric calculation that includes the differential pressures that occur across that, you're consistently going to get flow to those vent valves, which dilute any incoming deborated water.

And in that sense, the Framatome calculation is a much more sensible calculation than what is being done here. In fact, I don't understand why -- This is a great calculation from the neutronics point of view, and the input thermal hydraulics, but you left out the downcomer, and the vent valve.

Which would have been a simple addition to this calculation. Without that it's --

MR. DiMARZO: My case there is no mixing in the vessel. I take no credit for mixing in the vessel.

DR. RANSOM: Right.

MR. DiMARZO: It's what we concluded in natural circulation is that no matter what we did --

DR. RANSOM: Well, are you just looking for the worst situation to see if it works out?

MR. DiMARZO: There is no way -- it still is good. It still is very good. It still is acceptable. The worst possible thing you can think of with all the situations, it works out.

DR. RANSOM: It seems like it's very much away from the best test on the --

MR. DiMARZO: Absolutely, but it's acceptable.

DR. RANSOM: That's like assuming all the vent valves fail. You know, that they're not going to work.

MR. DiMARZO: But the point is in this set of calculations, we took very conservative assumptions on this pump, and we are already in such a situation. We could demote even further, but then we would have to revisit our more conservative assumption on the pump.

For example, the pump should go even faster, the slug should be even larger, and --

CHAIRMAN WALLIS: That's what I'm not -- that puzzles me. See, Vic is saying, "Yes, it could be more realistic about mixing, that's fine, it helps you. But then if you're more realistic about the pump, then make it 50 percent."

I'm not sure whether that carries me over the top or not.

MR. DiMARZO: But the point is this. In the pump case, even if it's benign, what will become the pump. Obviously, if I came here with the worst possible pump case, right, that I can fit in like I did on the natural circulation case.

And I tell you that's a problem. The immediate thing that you will say, say yes, but what I mean, if it's a little more realistic, maybe you wouldn't have a problem.

CHAIRMAN WALLIS: I guess what we're saying is if you're realistic all the way, with the mixing and your pump and everything --

MR. DiMARZO: We still get in trouble.

CHAIRMAN WALLIS: You still get in trouble?

MR. DiMARZO: Yes.

CHAIRMAN WALLIS: I didn't know that.

MR. DiMARZO: In this one here, I think we would. We could try. I mean, you know, but then you would come back and say, "Well, then build it less realistically," you see what I'm saying?

DR. KRESS: I don't understand the 25 percent pump. I mean, either it would pump on or have it pump off.

MR. DiMARZO: The pump comes on -- This is a 20 second transient. The pump comes to full speed in 20 seconds.

DR. KRESS: Yes.

MR. DiMARZO: The fluid has to catch up with it.

CHAIRMAN WALLIS: What is the relaxation time for this loop in terms of --

DR. RANSOM: Well, there again I would say you should do a thermal hydraulic calculation and test that model. You should investigate that finding.

MR. DiMARZO: That would give you -- But if I come up with 25, it's very low. I should come up with a higher velocity than he had.

DR. KRESS: The only thing -- I get what you said, but I mean there would be mixing in the vessel.

MR. DIAMOND: Yes.

DR. KRESS: Possibly if it was the pump, that might be enough to set it off.

MR. DIAMOND: Yes, in other words, instead of coming down to this point here, there was enough mixing so that you only came down to maybe 1000 and turned around and went up.

DR. KRESS: That's the non-part you're talking about.

MR. DIAMOND: That's right. Yes.

MR. DiMARZO: What is the situation here. We only have to say we shall not turn the pump on.

DR. KRESS: Which is the right thing to say.

MR. DiMARZO: That's what they say. So our point is to say on the natural circulation, which is the only thing that's on the table, what's the situation?

And no matter what we do there, taking all the most negative or conservative, whatever, we are okay. So as long as they don't turn the pump on, they're okay.

CHAIRMAN WALLIS: So your model in terms of the array is if they turn the pump on they get core damage.

MR. DiMARZO: Or we should do a lot more analysis to test.

DR. KRESS: -- have to do a lot more analysis.

MR. DiMARZO: But that's not on the table. They took the pump off the table. So it's not in the arena, and why -- you see what I'm trying to say?

CHAIRMAN WALLIS: Well, I guess as an observer, in terms of the public interest and safety, I'm not really interested in what's on the table. I'm interested in what's safe.

MR. DiMARZO: Right, but if this thing were not safe, to not turn the pump on is the same as they say, "We shall not turn the HPI off."

Now it's a matter of a regulatory point of view to figure out --

CHAIRMAN WALLIS: How much confidence you have in the operators following procedures.

MR. DiMARZO: Exactly. That's not the thermal hydraulic situation.

MR. SCOTT: I'll talk about that after the break.

CHAIRMAN WALLIS: You'll talk about that after the break. We're going to have a break soon.

DR. RANSOM: Isn't that a problem in every accident scenario?

DR. KRESS: Yes, that's not a unique --

DR. RANSOM: So I guess I don't see why it's so unique in this case.

CHAIRMAN WALLIS: It's not. Anyway, maybe we should --

MR. DIAMOND: I can conclude in just two minutes. I just wanted to show one last result from my calculation, which again showed the high void fractions that you could get into during this event.

But you see that this event is over -- well, in terms of void fractions -- over in ten seconds. I mean, there's only eight seconds here where there's voiding.

And as we said earlier, well, this core has been boiling for hours, so this is not what we're concerned with in this case. So my summary for the results here is as follows.

DR. RANSOM: When does boiling begin in the calculations you have made?

MR. DIAMOND: When does it begin?

DR. RANSOM: Well, you showed void fractions in some of the earlier ones, so obviously in that voids were being produced, I think for some earlier time.

MR. DIAMOND: Oh, when I referred to the fact that the core has been boiling for hours, I'm talking about the early phase of the small-break LOCA, in which the reflux condensation takes place.

Our calculation starts only after natural circulation has been re-initiated, and so the voiding that I'm talking about is only in that situation. Natural circulation single --

DR. RANSOM: Even that is going to drive closer to vent valves and going to dilute the deborated water as it comes into the valve pump. And I don't know myself what the mass of the borated volume of water is relative to the mass of the deborated water.

But that would be a dilution-type calculation that should be made, and that would be a more realistic boundary condition than the entrance of the core in this type of calculation.

MR. DiMARZO: That is correct, the question is in the issue of pump activation, do we want to do that or not? And that is what has to be decided in a different theorem. Because first decision we have to make is are you confident that does not turn on the pump?

And if the answer is no, then the next step is exactly what you proposed.

DR. RANSOM: I guess my argument would be if you're going to turn on 25 percent of one pump, why not assume they turn them all on. I mean, if you turn one on, it's better them all on.

MR. DiMARZO: If you turned them all on it would be much worse.

DR. RANSOM: Of course. So what is magical about one -- Why would a person turn one pump on?

MR. DiMARZO: Well, the pump -- there's only one pump.

DR. RANSOM: I understand that. No, there are four pumps.

MR. DiMARZO: Yes, they could bump the

whole array and it would be much worse. Definitely. But the problem here we have established. We are trying to establish that you should not touch the pump. Period.

Now, let me come to regulatory question. If you are not sure, and you make the determination, look in past history and whatnot, we cannot for sure rule the fact out that they've already turned the pump.

Then our job is to go do a dilution study on the downcomer, the AVV, everything.

DR. KRESS: We've got a real problem.

MR. DiMARZO: I mean, we've got to move the whole thing, definitely. Absolutely. The premise here is --

DR. KRESS: And more than likely you will have a problem with the fuel lead.

MR. DiMARZO: I don't know the answer of what happens, but I've got do a really good analysis. Now, my issue at the beginning as I started I said, in the way this has been framed, which is no pump, I can essentially say that as long as that's a sure statement, there's no pump, and I'm not making any qualifications to that.

If you stick to natural circulation, there is no way you're going to have a problem.

CHAIRMAN WALLIS: All this is for the numbers where the B&W --

MR. DiMARZO: Right, but the other one, you have a problem storing the slug in the first place. So if you go natural circulation or even bump pump --

CHAIRMAN WALLIS: All these numbers have been worked out for a certain kind of B&W plant.

MR. DiMARZO: And we could do that too for them. But the problem is that the --

CHAIRMAN WALLIS: Yes, but someone is going to reach the conclusions about what should be done about a Westinghouse plant, from the calculations for a particular BNW plant?

MR. DiMARZO: No, the slugs are much, much smaller. I mean, it's again an area where we can embark on, but the scenario's completely different, because the volume in which they can store the slug is very, very small compared to what is here.

Here we're dealing with 23 meters cubed potential area of storage, over there it's a 2 meter cube, that's it, it's very -- the loop is sealed, so you cannot use that.

You just have little pieces of --

CHAIRMAN WALLIS: But they still probably shouldn't bump that pump.

MR. DiMARZO: Well, with that kind of volume, now the question is what does it do? That's exactly what we can ask ourselves When you take two liters and you put it in 200 liters and you transfer that into the core, what's going to let -- How are you going to keep it together?

That's going to be very complicated to do. I think it's not an analysis. In other words, you can do a rough analysis of that and basically prove that there is no way you can keep this thing together through the downcomer.

CHAIRMAN WALLIS: I suggest we let David finish his presentation, then we have a break. And then we'll come back to all these other questions and we have some more presentations by the staff.

MR. DIAMOND: I'll just summarize my thoughts on the pump start case. The initial peak fuel enthalpy increase was 30 calories per gram as we talked about on the fraction of a second or 60 calories per gram, we're talking about maybe one second.

But more important than that is the fact that the maximum pellet average fuel enthalpy got up to 185 calories per gram, up in the range where we saw that one would certainly have melting within the fuel, and our calculation where we used 3000 Kelvin as the melting point.

CHAIRMAN WALLIS: I think David, when you're presenting to the -- if you're presenting this to the full committee, I think that you ought to put the temperatures in there too. In your slide, you can do that?

The significant number of the elements, including perhaps the high --

DR. KRESS: I think that one-eighth core case made the core --

CHAIRMAN WALLIS: Yes, but it's not in the summary slide. The temperature -- I know there's points to be made. In terms of summarizing things, put it on the slide.

MR. DIAMOND: And again, as I said before, the void fraction, we have DNB, but that's not a concern here. It's this one that's a concern.

CHAIRMAN WALLIS: Well, it looks as if there isn't really that much cooling of the fuel elements. They get heated up and they cool off later on, but lead up -- the heat input is a much bigger term than heat removal, so DNB doesn't matter that much.

So this is a good time to take a break. Could I have an estimate of how long we're going to be after the break?

MR. SCOTT: I have about a half a dozen slides.

CHAIRMAN WALLIS: There's probably going to be a lot of questions from us. Yes, okay. So we'll probably be at least another hour after the break. Maybe two.

Okay, so we'll take a break for fifteen minutes. Come back here at 3:15.

(Whereupon, the foregoing matter went off the record at 3:00 p.m. and went back on the record at 3:16 p.m.)

MR. DiMARZO: We have the slide. And the first bullet is really all that we are trying to close upon at this point. And what it is is that we are seeing, we have tried to -- Actually, we have not tried.

We have calculated the largest possible slug at the fastest possible rate of transfer, and -- in the system that you could come up with. That physically could be arranged, and in spite of all this, we did not have any indication of a negative effect that brought concerns.

CHAIRMAN WALLIS: So you know that 90 calories per gram is not a problem?

MR. DiMARZO: That's basically under what Kevin concluded and that's what we are saying.

CHAIRMAN WALLIS: Do you have a fuels person who reassures you that that is the case?

MR. DiMARZO: Okay, well we can do that.

MR. SCOTT: Well, because it's slow.

CHAIRMAN WALLIS: Well, how slow does it have to be. I don't know -- I don't know anything about fuel failures.

MR. SCOTT: Well, at the June 26 meeting, it was mentioned that it has to be less than 30 milliseconds. The power supply transient has to be less than 30 milliseconds at this kind of a 100 calorie, 1900 calorie per gram, to cause fuel damage.

If it's greater than that, it's probably not going to cause fuel damage. And these calculations -- David has like half a second or a second. I mean, the spike is --

MR. DIAMOND: No, we're talking about many seconds to get up to 90 --

MR. DiMARZO: Yes, well, we're only talking about 20 seconds. So what we are trying to conclude today, based on what we showed you today, is that in the case associated with the natural circulation transfer of the slug, we are confident that no matter what we do, we're not going to cause more severe --

CHAIRMAN WALLIS: What centerline temperature are we looking at in this case? Which centerline temperature?

MR. DIAMOND: Well, assuming that you get up to 100 calories per gram somewhere, so that's half of what we were talking about -- Before, we were at 3000 centerline. I'm thinking of the different --

CHAIRMAN WALLIS: It starts at some value, so.

MR. DIAMOND: Well, it starts very low.

CHAIRMAN WALLIS: And then someone has some number that it's okay if you don't go above, say, 2000 or something?

MR. DiMARZO: He said 3000.

MR. DIAMOND: Well, I was using 3000 Kelvin.

CHAIRMAN WALLIS: Then you said there was a problem with that.

MR. DIAMOND: Sorry, what?

CHAIRMAN WALLIS: 3000 Kelvin was a problem, or was it borderline, or what?

MR. DIAMOND: No, I said I was using that as the acceptance level for what the fuel temperature --

CHAIRMAN WALLIS: This is some degree?

MR. DIAMOND: -- Kelvin is roughly the melting temperature of the fuel.

CHAIRMAN WALLIS: Is there some agreed upon acceptance criteria or something?

MR. DIAMOND: No. The --

DR. POWERS: I think it falls on one of the fuel damage curves.

MR. DIAMOND: Yes, the only acceptance criterion that we have now is 280 calories per gram. However, a lot of people feel that we should not have melting anywhere within the fuel pellet, in order to preclude any kind of potentially catastrophic fuel damage.

MR. SCOTT: And I think in the standard review plan, there's something called Specified Acceptable Fuel Damage, or SAFD, and one of those is no fuel melting. So that's why you don't operate a 20 kilowatt plant.

CHAIRMAN WALLIS: So there is a place where it's written down.

MR. SCOTT: Yes.

CHAIRMAN WALLIS: No fuel melting is the

criterion? It's not just a lot of people feel that there is some sort of authoritative reference?

MR. SCOTT: Yes.

DR. KRESS: I notice then this reason why the rate which is --

MR. SCOTT: Okay.

MR. DIAMOND: Why the rate matters, or why it does not matter?

DR. KRESS: It seemed to me like it shouldn't matter. Maybe you'll tell me why it matters.

MR. SCOTT: If we're claiming that fuel damage would be something like a crack. If I get sort of a small crack.

DR. KRESS: Which would do what, the internal pressure will --

MR. SCOTT: The pellet expands. In these high burn-up rods, the pellet and cladding are sort of in contact, and if you have rapid expansion of the pellet because of heat build-up, it can crack the cladding. And the cladding has to have hydrates in it, or oxide layer.

DR. KRESS: So it's the rate at which it expands

MR. SCOTT: Because there's an additional mechanism besides just frontal expansion. You have the fission gaps that's in the edge of the pellets. Because of the high power profile, the high burn-up in the edge of the pellet.

That gas which is little bubbles, expands because it's at a high temperature, and now provides not just the sort of manic load but actually pushes the pellet pieces against the clad. And that gives you extra --

DR. KRESS: If you add the energy of the rate that gas has a place to go, would you say?

MR. SCOTT: Yes, this is a theory. And it seems to be borne out by the tests. They do these tests, if they do them fast, less than 20 milliseconds, they get cracking in the clad.

If they do them slower, they don't. The same energy --

DR. KRESS: You say they've got data.

MR. SCOTT: Yes. Data shows the difference between --

DR. KRESS: I don't care about the mechanism. You've got data, send a sample.

MR. SCOTT: We've got data.

DR. RANSOM: Where's the data from, CDF?

MR. SCOTT: This is the Japanese reactor, nuclear safety research reactor, NSRR. Their pulses are five, six, seven milliseconds. The debris reactor plants does nine, twenty, forty milliseconds.

CHAIRMAN WALLIS: We had a presentation on this fuel damage types in the core, and someone drew a blue line. Of course, it wasn't very convincing as a boundary.

And it was somewhat under 100 calories per gram, I think. It gave me the impression there really wasn't much of an experience base, and that people were thinking and guessing and hoping, rather than being sure that with these numbers you would not get fuel damage.

MR. SCOTT: The assumption is that you can make some adjustments to data points that are done under non-typical conditions to sort of the reactor case. If you know how to do that. Then those data points may form a more coherent --

CHAIRMAN WALLIS: But this is somewhat iffy business. One should err on the side of being conservative?

MR. SCOTT: Well, I think Dr. Diamond got 35, 40, 50 calories per gram, which is substantially less than 100.

CHAIRMAN WALLIS: That's in the rapid heat pump. In the rapid pump.

MR. SCOTT: I mean, with natural circulation, you're talking about natural circulation --

MR. DiMARZO: Remember, the case B in which you got 100? It's the case that we did just to explore some uncharted territory, or practically uncharted. Case A, I think we were on A, let me think.

CHAIRMAN WALLIS: So no one -- Does anyone plan to present a curve like what we saw when we got this presentation on fuels where there is some Capri data, and here's some Japanese data, and here's where we are with these reactors, and that's why --

MR. SCOTT: October 9, there's a summit meeting.

CHAIRMAN WALLIS: That's too late to help us.

MR. SCOTT: Well, we have that, we'd like to show it as a Paintbrush slide.

CHAIRMAN WALLIS: Yes, that's the one that -- That's right. Could you show us that?

MR. SCOTT: You want to see that again?

CHAIRMAN WALLIS: At the full committee meeting?

MR. SCOTT: What we were trying to do was to put together a full picture for you.

CHAIRMAN WALLIS: Well I like the Paintbrush slide. It gave me some perspective on the state of knowledge. I like to compare that with what you're telling me with words here. Can we see that? If you want to bring it in, in half an hour?

MR. SCOTT: I could go out and get it.

CHAIRMAN WALLIS: Or send somebody?

DR. POWERS: I think we're going to have a problem because there's a lack of calculations here. What you will see in the Paintbrush slide is that when we look at the fuel that Dave calculated for fresh fuel, then you'll see that that slide says, "Gee, that fresh fuel could tolerate, not 280, but maybe as much as 200 on a good day, maybe as much as 150 calories per gram in that initial pump."

You'll see in the Paintbrush slide that Dave went out and he calculated for a high burn-up fuel, that, depending on who you believe, if you believe NRR it's 180 calories per gram, the high burn-up fuel tolerates.

If you believe me, then we will say well, maybe 18 is what it will tolerate. But we don't have a calculation for that high burn-up fuel.

CHAIRMAN WALLIS: Well I find it easier to believe you because you're some identified. NRR is some vast conglomerate. Consensus may not be wisdom.

DR. POWERS: Well they may know more about it than I do.

CHAIRMAN WALLIS: Well, this is a concern with me, though. Because I hear you say 18 and all that. What should we be concluding about this?

DR. POWERS: What you conclude is pretty much what Dave said. Was that for this calculation, and the prescribed fuel-management scheme, that if we went to the bottom, everything's okay.

There's another clause that's omitted from this conclusion slide, and that is for the prescribed fuel-management scheme, what happens in this reactor? Okay, and so on.

That's the comment that I would make, is that you've left out one of the assumptions, and that in your calculational suite is that you took a prescribed fuel-management scheme.

CHAIRMAN WALLIS: But there are all kinds of creative fuel-management schemes which are being worked on.

DR. POWERS: No, well, not only that, there are mistakes made in fuel-management schemes.

MR. SCOTT: But in general, a high burn-up rod cannot reach the same kind of power --

DR. POWERS: That's right. And that's why you can't translate what's been done here to the high burn-up rod, because you go nowhere near

MR. SCOTT: No, he has high burn-up rods in his model.

MR. DIAMOND: Yes, we do have high -- Well, they're not that --

DR. POWERS: You've got the high burn-up rods with control rods

MR. DIAMOND: Yes, but they still reach high centerline temperatures. Now that is --

DR. POWERS: They're talking about the initial pulse.

MR. DIAMOND: Those are not high. Okay.

DR. POWERS: Okay. And you just don't have anything.

MR. DIAMOND: Oh, the initial pulse. Yes. There is a lack of data, yes.

DR. POWERS: I mean, the long-term transient. I mean, the slow build-up of power is going to be a quasi-static pressurization of fuel. And that 2900 I have every confidence in the world that that fuel rod's going to pop. Okay?

What I don't know is the natural circulation calculation. Some of them like to pop at

1500. But you put 100 atmospheres on those fuel rods, and they'll bust.

MR. SCOTT: If the high burn-up fuel is at 100 calories per gram --

DR. POWERS: It's going to bust.

MR. DIAMOND: Yes, okay, but all we have is conventional wisdom. We don't have hard numbers of the fuel damage limit. And when we're talking about numbers like that, of course, I mean the numbers that I'm showing have a plus or minus associated with them as well, so.

MR. SCOTT: If I have a pressure inducer in this little test rod that I'm going to put through this transient, for saying these fission-product vapors, are they going to show up on that device?

DR. POWERS: At 3000 degrees Centigrade?

MR. SCOTT: Or less, maybe, let's go down to --

DR. POWERS: 2900 degrees Centigrade? I'll give you 100 degrees. Yes, you're going to be vaporized for a high burn-up rod. For a low burn-up rod --

DR. RANSOM: Do they know this or do they assume there won't be any flow axial in the rod. In other words it's just local.

DR. POWERS: Yes, I mean you've got roughly a mole of cesium in there. Okay?

DR. RANSOM: No way for it to escape up the rod to the plenum?

DR. POWERS: It goes -- You can pressurize the plenum all you want to, it's three cubic centimeters. Okay?

DR. RANSOM: Well, but it's going to have a pretty mitigating effect. This is a mobilizing effect to set down on the rod?

DR. POWERS: Yes, I mean the fuel, the bubbles themselves are at astronomically high pressures. Okay? But this quasi-static pressurization occurs when those bubbles release to the gap.

There really isn't much of a gap here. And if it's not -- I mean the quasi-static is pressurizing the fuel rod like it was a pressure vessel. Except with high burn-up it's full, okay?

Because it has, I mean it's sitting right at the boiling point of 300 degrees Centigrade. I mean, it hasn't gotten any thermal relief whatsoever. And so now you've put a large pressurization, because you've melted and boiling fuel, and the boiling fission part acts like a centerline. It causes static pressurization.

But I don't know that that's happened here because we don't have -- I mean, you've got fairly slow calculations for the natural circulation phase. And that's why I say you just need to put one more caveat into what you've got here, and that's that you've assumed the fuel-management scheme.

DR. RANSOM: Can we carry that a little bit further. What are the consequences of me -- Let's say you damage the rod.

DR. POWERS: If you bust it, the big problem is if you dump the fuel. Disperse it out of the rod.

DR. RANSOM: And then you've got to clean it all up.

DR. POWERS: That's not the problem. If it slumps down, and you put it in there --

DR. RANSOM: The entire core, or just a few drops?

DR. POWERS: The 20 percent that he was talking about, okay? If I dump 20 percent --

MR. DiMARZO: Twenty percent in the pump case?

DR. POWERS: In the pump case, but I if I had 20 percent of it down there, I would have a criticality problem in the lower plenum. I mean, you're going to have a major clean-up problem, but it's going to be an oscillating criticality event.

MR. DiMARZO: Right, but the pump case --

DR. POWERS: That's right. That's right. Yes.

MR. DiMARZO: But with that caveat, what it's saying essentially, our strategy has been to take a very crude thermal hydraulic analysis -- very, very crude, not conclusive on a lot of things -- and pass it to neutronics, where we spent most of our effort.

CHAIRMAN WALLIS: It's not crude, it's limited.

MR. DiMARZO: It's limited situation. The first one --

CHAIRMAN WALLIS: In the natural circulation case, you were looking at the worst thing that could happen. No mixing, where there is mixing, and only fuel mixing where you know there must be mixing.

MR. DiMARZO: Right.

CHAIRMAN WALLIS: And the biggest slug you could possibly jam into the space.

MR. DiMARZO: And zero borated water running into --

CHAIRMAN WALLIS: So I think you need to

make that clear, that you've made the worst case assumptions.

MR. DiMARZO: Very, very worst case. No internal vessel circulation, no downcomer mixing, nothing. Given that, which is really very, very aware from best estimate possible sense, it's really -- We have difficulty creating a problem, in a sense.

So that leads us to this statement, which has to be a -- but that's the first five. Now that leaves another issue. Which -- Actually two other issues.

The first issue is what about non-PWR, BNW, lower vessel for this configuration? In all those, the storage space that is available to you is not 43 meters cubed, but is more rather one or two meters cubed, because you're only dealing with the legs, with the loop seal and so forth.

CHAIRMAN WALLIS: See, then the worst think you could generate is not enough volume, but there --

MR. DiMARZO: Above, they're above, so you can't store because it flows out. And so, essentially, you are limited in what you have, and when you start moving such a thing, the first thing that happens is that the tail starts to choose the form.

And at that point there is no way of

getting that kind of a deep type problem that he was mentioning.

CHAIRMAN WALLIS: Have you looked at international work on this boron problem?

MR. DiMARZO: Yes.

CHAIRMAN WALLIS: Is it just your work, or did you make any comparisons with other people's work?

MR. DiMARZO: They did all kinds of different scenarios. Mostly they are pumped.

CHAIRMAN WALLIS: I remember when we visited --

MR. DiMARZO: They have a pump.

CHAIRMAN WALLIS: -- the Germans seemed to be very concerned about this boron problem. But you're saying it's not a problem. Is that because they pump?

MR. DiMARZO: They have the pump.

DR. POWERS: Well, I think that the Germans are concerned with the build-up of unborated water during the shut-down operation. And then that pumps a transient.

MR. DiMARZO: It's not a small-break scenario. It's another scenario.

CHAIRMAN WALLIS: It's a completely different scenario.

MR. DiMARZO: It's not decision, in other words, this is a small break.

DR. RANSOM: And you use the steam generator, you get the boiler condenser more easily as reflux from the up B2, which means it drains back to the hot leg and directly into the core.

MR. SCOTT: That's the answer. The Germans have this so-called ROCOM a large, Plexiglass, they're looking at mixing in the downcomer as well in the lower plenum. But it's for other scenarios besides the small-break LOCA; there's the so-called Finnish scenarios, there's a Swedish scenario, there's four or five of these dilution-type scenarios. And most of them may even only have leakage backwards through the steam generator.

MR. DiMARZO: Secondary leakage in the back.

MR. SCOTT: So you can get unborated water.

MR. DiMARZO: There are a lot of scenarios here that can get you into trouble, no question about it.

CHAIRMAN WALLIS: That's not part of this --

MR. DiMARZO: But in this issue.

MR. SCOTT: There's a PKL we're actually a part of that --

CHAIRMAN WALLIS: So this GSI isn't about all boron transients, it's just about small-break.

MR. DiMARZO: So we would like to basically wrap up the natural circulation part of this issue. What about the pump part? Well, the pump part is such that our indications are that we're going to have a problem with the pump at this level of the game.

Therefore, the idea here is to establish whether we believe that this pump is not going to be turned on, or not, in a probabilistic sense. And that type of situation.

So, if the answer to that is we don't believe that the pump will stay shut off, the only consequence to that is a full-blown, CFD-validated and experimental course of action to establish what is the mixing in the downcomer, lower head, RVVs and all that.

CHAIRMAN WALLIS: This would most likely be the operator's mis-diagnosing the transient, so that they start the pump thinking they have a different kind of transient?

MR. DiMARZO: They don't recognize that they went to a BCM, for example, and so forth.

DR. POWERS: Yes, they recognize that these are applied --

MR. SCOTT: Let me at least do my thing, I think it's -- They have to know what the symptoms are so they can make a decision.

MR. DiMARZO: Yes, but wait a minute. That's the key situation. Now, I want to point out that this has been done, so far, with very little involvement of effort and time, the Brookhaven being the lion's share, and then this analysis that you asked me in an hour, in 20 minutes I come back with another curve.

So it's not that this is a big thing. Now, the one that we are talking about, which is discussing the pump issue full-blown, is a completely different story.

And we had a plan for that, we priced it and everything, and that was a very massive thing. That's why at Research we decided to break it down into these two areas, and present it.

CHAIRMAN WALLIS: So you're proposing to close the issue, aren't you, on the basis of some --

MR. DiMARZO: If the presumption -- I'll go a step further. So we say that pump is not an issue. Pump, we can deal with pump. So what we are saying is that if we can convince ourselves that the operating procedure as such, that the pump will not come on at the end of the day.

CHAIRMAN WALLIS: But you can't do that. You have to look at probability of this happening.

MR. DiMARZO: Right, I'm not making the statement that we have done that part, okay? All I'm saying is, if we can convince ourselves that the pump are not going to come on at the end of the day, then we recommend --

CHAIRMAN WALLIS: That's not a yes or no, it's a probabilistic argument you have to make, presumably. You get into this human factors PRA, and then -- It's a bit of a jungle.

MR. DiMARZO: Yes, but at the end of the jungle you come out with some estimate that will tell you I'm okay or I'm not okay.

CHAIRMAN WALLIS: But you can't recommend closing the issue without a thorough discussion of human factors and the probabilities and why you've reached this conclusion.

MR. DiMARZO: Exactly.

MR. SCOTT: Oh no, I don't think that would necessarily be true.

CHAIRMAN WALLIS: You don't think so?

MR. SCOTT: No. We don't examine in detail every transient that's possible. We think we don't look at a lot of details of severe accidents. The risk inform guys were here a month or two ago, it sounded like there were certain -- they had cut-offs in these metrics, they just don't keep looking.

MR. ROSENTHAL: Even though I have a good excuse, at the very beginning, Harold spoke about a risk of like a one minus five event as the estimate.

And now, even if you say one out of ten in human performance, you are going to be -6 or --

CHAIRMAN WALLIS: Well that's what you get when you --

MR. ROSENTHAL: When you say that you have -- This is not, a minute's time response, which that human recovery curve looks like, the next dimension, that ACR model.

But is a couple of hours out in time.

CHAIRMAN WALLIS: It's into the next shift. It's not -- It may be in the next shift of operators.

MR. ROSENTHAL: It's not when you're doing critical or turnaround --

DR. POWERS: This is an error of commission. And nobody has a clue what probability to attach to that. And the longer the time, the more likely it becomes there is an error of commission, rather than an error of omission.

MR. ROSENTHAL: Because of thinking.

DR. POWERS: Yes, thinking, that's right. And these are highly stylized accidents we're looking at here. The real accident has all kinds of permutations. The kind of people that react, and make errors of commission.

CHAIRMAN WALLIS: Something else happens as well, like in TMI, they get confused.

MR. ROSENTHAL: That's right.

CHAIRMAN WALLIS: So you need to quantify this, and you're going to quantify it by saying it's a 10^{-5} event and out of the blue you're going to say it's only a ten percent chance that they'll make this error of commission? That's going to be the rationale?

MR. ROSENTHAL: Yes.

CHAIRMAN WALLIS: What's the basis for this ten percent error of commission assertion?

MR. ROSENTHAL: No, that -- What I said is that all you have to do is buy yourself the order of magnitude.

CHAIRMAN WALLIS: So how do I know it's reasonable?

MR. ROSENTHAL: I use my HCR model, I mean not on the spot.

DR. POWERS: Wouldn't you -- I mean, you're going to get the argument here. We have sensitized everyone to this, they'll train on not bumping the pump. And that will keep the error of commission rate down.

I mean, we presume that's there some sort of an error-shaping factor, even associated with errors of commission.

CHAIRMAN WALLIS: But would they fail to bump the pump at other times when they should be pumping?

DR. POWERS: That may raise the probability there.

CHAIRMAN WALLIS: No, seriously.

DR. RANSOM: Are there situations where they should bump the pump?

DR. POWERS: Yes.

MR. SCOTT: If you go into my hand-out, come to this page, and we'll start from there. So I'm going to go Framatome, Combustion, Westinghouse, and we'll talk about what they did and --

CHAIRMAN WALLIS: This is the other reactors?

MR. SCOTT: In the agenda you mean?

CHAIRMAN WALLIS: This is not BNW, this is other types --

MR. SCOTT: Well, I'm going to start off with BNW, and I'm going to show the procedure for Combustion and the procedure for Westinghouse, and talk about starting the pumps.

CHAIRMAN WALLIS: Okay, so Framatome covers all of these kinds of reactors.

MR. SCOTT: No, Framatome covers BNW reactors.

CHAIRMAN WALLIS: Oh.

MR. SCOTT: I'm sorry, this is the BNW Owners' Group guidance. It's published by Framatome.

CHAIRMAN WALLIS: Okay. Well they also have Westinghouse reactors?

MR. SCOTT: No. They make fuel. Well, in Europe --

CHAIRMAN WALLIS: In Europe they have Westinghouse reactors. Okay, that's where --

MR. SCOTT: This is U.S. OTSG type. So as we've said there's the -- You can get the boron dilution from these kinds of whatever model -- And this is what, Victor, you were talking about.

You have steam blowing around because there's no pressure, that the vent valves can open. And I'll show you a picture that, because think of the last meeting, Sandro didn't want to see a picture of that.

But there might be voids because we've been sitting around without pumps for awhile. This is another way to get some reactivity, just the fact that once you cool the core off, the voids disappear and it adds a small amount of reactivity.

But the procedures say, and the guidance say, and at this point in the accident, the technical support center guys are sort of running the show. If this, then do not start the RCP. If I see there's several places in this procedure guidance.

So here's the criteria for starting the pump. If sub-cold two natural circulation verified for 60 minutes, and sub-coolants greater than 30 F, or if one loop is verified for 210 minutes.

And you've had high-pressure ejection flow. In this case you want to start the coolant pump in the loop that has natural circulation flow. So, it looked to me like they have drills and training and guidance that gives them a substantial reason to start the pumps only if they sort of know they have natural circulation, which we already show has moved the unborated slug to the core.

CHAIRMAN WALLIS: If you have natural circulation you've already cooled the core.

MR. SCOTT: Yes, and --

CHAIRMAN WALLIS: Time is on your side. Why would you want to start the pump, unless you want to start the whole reactor again?

MR. SCOTT: Well, I have a slide here that's going to give you some reasons why they --

CHAIRMAN WALLIS: Restart?

MR. SCOTT: The next one, if you'll go to the next one, we'll talk a little bit about why they want to start it. Because this may come back to this idea of, well, what if they do it inadvertently. If they're really anxious to start it, then there's pressure to start it.

But it looked to me like -- I mean, we once thought after Three Mile Island that the first thing the guys are going to do is get the pump going, get the pump going. But these are some of the reasons why they would want to do it, and they don't seem to be that significant.

You would like to get the pumps going because you want to try to control pressure, and you want to control cool-down. I mean, if I don't have -- I could get pressurized thermal shock if I cool it down too quickly.

I think there were two reasons here, I

don't now see the second one. Well, let's say you don't have pressurizer spray flow, because that comes from the -- at least in these machines -- you have to have a pump running to get the pressurizer.

Now, you have to get pressure control back. You'd really like to get back to something that's stable. If you have sort of on and off flow, you're going to get --

It just doesn't look too good. So there are a couple of reasons to try to get the pumps going, but it didn't appear to me to be particularly urgent.

DR. RANSOM: Well, in this sort of scenario, what's a long term? I mean, your break is only about --

MR. SCOTT: Well, if you can't isolate it it's still open. Hopefully by now you've got whichever HPI pump wasn't running before is now running. You're filling the system up. You're coming back to an equilibrium.

You're starting to cool down.

DR. RANSOM: Now I'm wondering why would you ever want to start the pump under those conditions? You know, natural circulation has got you cooled down, and --

MR. SCOTT: If you want to stay on natural circulation, if you're confident it won't quit on you, then you could stay on it. If you've got plenty of water going.

DR. RANSOM: What good would starting the pump do?

MR. SCOTT: It would help you cool down better. It would stabilize --

DR. RANSOM: But you're saying, well, if the HPI were to fail, even under those conditions, you're still in trouble.

MR. SCOTT: Well, you could last a little bit longer if you had some coolant flow. That may come up in the Westinghouse. Let me now go to --

CHAIRMAN WALLIS: Now wait a minute. These are for certain classes of small-break accidents only, aren't they?

MR. SCOTT: That's right. If the break size is too small --

CHAIRMAN WALLIS: How do they know they're in that class of accident, and not in something else?

MR. SCOTT: Well, if it's a larger break, the pressure probably would be down much faster. If it's a smaller break, the pressure might have hung up higher. I don't think it matters exactly what break size they have.

The question that matters is do they think they have a pocket of unborated water. They would know if they did in BCM. You would probably know if you had.

MR. ROSENTHAL: If I may, let me throw in a couple of comments. One of the considerations on running pumps is it basically just makes it much easier to control your plant.

And it is desirable to be there if you feasibly can, and you don't have a risk otherwise. With respect to if the pumps are not running and restarting them, notice what Harold put up there is independent of any kind of an accident.

These are things that the operator can see and respond to. Not that one, but the one with just the criteria. It makes a difference whether you've got a LOCA or anything else.

Here are the criteria. So when we start to, for example, make comparisons to the TMI accident, remember these kinds of things weren't in place there. Today you have it laddered such that you can't turn off HPI until you have established some coolant direction and you've got levels.

Those things weren't there. It makes no difference what kind of an accident you have ongoing, it is those criteria that essentially ensure what you've got the conditions in that will give you core cooling.

CHAIRMAN WALLIS: So it's having HPI running which is key?

MR. SCOTT: Well, for example, let's say you had no steam generator heat sink. There would be no point to run the pumps. Even if you pump water over the generator, you're not going to get rid of the heat.

So in that case you're in feed and bleed mode. You've got to hope you get your energy through the break, and you can keep pumping in cold water. Now, this is from the -- this NUREG is the safety evaluation report for the combustion engineering AD plus system.

In that safety evaluation report, they determine that this particular small-break LOCA scenario with boron dilution was satisfactory; would not be a problem.

It didn't go into a lot of details, but one thing we did notice was if you can keep the boron at or above 550 ppm, at this low temperature, you would not get any power spikes.

And as we've said before, only during the beginning of the cycle. At later times in the cycle, this number could be lower. I think we saw the numbers that Marino added, it dropped down to about 500?

Yes, the minimum was --

CHAIRMAN WALLIS: This is the boron during a transient? Or is it -- What's --

MR. SCOTT: Yes, yes, the boron infusion.

CHAIRMAN WALLIS: How do you know what the boron is during a transient? You have to calculate it.

MR. SCOTT: The guidance would help.

CHAIRMAN WALLIS: So --

MR. SCOTT: But you calculate it.

CHAIRMAN WALLIS: I don't see it what this helps you. You have to now predict whether or not you have a boron of 550 ppm.

MR. SCOTT: Yes. I'm saying, so for many transients, I think the boron started at 2500. I think even in this particular plant what they did was they raised the boron, such that maybe it starts at 3000. If it only drops down to 700, they're okay.

CHAIRMAN WALLIS: Is this using exactly -- This is not using the same thought process you used --

MR. SCOTT: No.

CHAIRMAN WALLIS: Now, what models did they use?

MR. SCOTT: They used mixing in the downcomer, mixing in the vessel, but no mixing in the steam generator outlet plenum, as I recall. So they sort of did the opposite. We assumed --

CHAIRMAN WALLIS: But we just saw earlier on there was a CFD knot model, mixing Framatome, yet they've used similar models?

MR. SCOTT: You can get experts up here that will tell you CFD is great stuff, and that you can do that. He doesn't believe it, but other people do. Jack has guys working for him that believe it, and convinced him.

But now notice the thing here. See, once again, the tech support center guys are running the show, but they only require 20 minutes under natural circulation, not an hour.

MR. DiMARZO: But I think if you do 20 minutes of this natural circulation, this thing is long gone. Rolled back --

MR. SCOTT: The bubble has gone around to its --

MR. DiMARZO: So if the requirement for a restart is that you establish first natural circulation, right? And if you have natural circulation for one loop flowing, one loop turnaround, you can do whatever you want.

There is absolutely no issue. So if that is a requirement for everybody, for example, then you can take the thing off the table.

MR. SCOTT: Just one second. So there is some mixing down here. They only had -- It's in much smaller volume, in their machine, in the BNW machine. And their minimum boron was only 1350, so they were way, way higher than this slide.

So that's why they have two --

DR. FORD: So when the question -- I'm just trying to follow the rationale. When combustion engineering came up with these criteria, how did you read them? How did NRR read them?

MR. ROSENTHAL: Wait, let me just say that Warren Line has been that in the reactor systems branch since Mother Earth, and I know because I was --

(Laughter)

MR. ROSENTHAL: But the trouble is that I was his supervisor when we reviewed B&W Web Zero of the two point procedures and he also was the combustion number and has been involved ever since. So Warren I --

MR. SCOTT: Tony Etarda, I think, is the one who probably did the review of this.

PARTICIPANT: I can speak to BNW, they're up to reg nine, by the way, but I have not been involved in detail with the combustion work in the past few years, so I would defer to others.

MR. SCOTT: They asked for specific analysis, so when combustion was submitting the AD+ design, one of the requests for additional information --

DR. FORD: I guess, my question's more procedural, really. That for the Babcock designs we cited, CFD doesn't work. And we went into this simplified, slug-flow thing.

But an earlier submission, this combustion one, we decided it was okay. So what changed?

MR. SCOTT: I guess either different people doing the review, or maybe the scenario was slightly different. The modeling was a little bit different. I mean, I maybe could accept CFD in one case, and not in another.

DR. FORD: So, how does NRR decided which is the correct procedure for reviewing?

MR. SCOTT: I guess I don't know.

CHAIRMAN WALLIS: I think these are very good questions that you keep asking.

PARTICIPANT: NRR effectively took a look at the configurations and reached a conclusion that the BNW design that makes the steam supply system, was the most challenging with respect to this boric acid dilution situation.

That's the one that we should look at first. And we basically asked research to give us a hand with that. Go back, study it, and come back and tell us what their recommendations were, what their findings were.

We were not as concerned on a judgment basis with the combustion in the Westinghouse design. Principally because, as research has told you today, the volumes were much smaller, and in our judgment, the concern just really wasn't there.

CHAIRMAN WALLIS: Well, that's what you should be telling us. I mean, this business of mixing minimum boron and 1350 doesn't tell me anything. I don't know what kind of boron to expect, under what conditions, under what assumptions, or what?

It doesn't really tell me anything. And if you would do a de matso type limiting analysis for CE and come back and say, "No problem," then you've got some sort of comparison basis.

Do you see the difficulty I have? Maybe it's the difficulty my colleague has too.

MR. SCOTT: Well, the point seems to be that somebody already did this, and looked at it, and accepted it. I don't know, they may have had -- combustion may have provided some assessment with that model.

I mean, that's what we would do. If somebody gave me a CFD answer, and said, "Well, here's the basis for that. Here's the assessment document for these particular calculations, or this particular code," and I was happy with both of them, then I would accept the conclusion.

I wouldn't necessarily have to go off and redo the calculation, or do a sensitivity study if I was willing to accept it. Since I didn't do that review and didn't actually talk to anybody who did it, I can't give you the details of why they accepted it.

PARTICIPANT: We do not specifically and continuously review all aspects of the emergency procedures guidelines for the emergency procedures. What we effectively did in past years was conducted a review that terminated when we reached a conclusion that they essentially had it covered.

And we then told them, go ahead and continue with improvements as you recognize them. While we retained the right to go back and select how they look into these things as they come up, if we need to.

So with respect to emergency operating procedures, we very well may not have looked into the kind of detail that you are being shown here. But we certainly have the right to go back and do that if we feel that it's necessary.

MR. ROSENTHAL: Let me look at the top half of the slide. First of all, if you would just do static presence calculations, broad ones, for a typical pressurized water reactor, you would say that typically about half the rod worth is tied up -- half the reactivity that's being shut down in this cycle is tied up in these rods.

And about half of that is soluble boron. It's not unusual at all to see that about 300 -- Assuming that you put all the rods in. You pull the plant down, about 300 F, you run out of rod worth, assuming all the rods were at maybe 350 where most reactors start rods.

And you see you've got to get some boron in there. So the first statement is simply, they're saying, "Hey look, if you're trying to cool this plant down, you've got all the rods in, you've got five, six hundred ppm, you could cool it all the way down.

You're just not going to go recritical."

Okay, take that and put it on the shelf. The next set of points is they're saying, "Hey, wait a minute. There's a restart strategy." And if you take that restart strategy, you say, "I'm not going to have a problem with a deborated slug causing me a recriticality."

CHAIRMAN WALLIS: It doesn't that, though, it just says, "Here's the strategy." There's no conclusion.

MR. ROSENTHAL: Yes, but, I mean, but think of all -- And so I don't even need the third bullet, because I know that if the 20 minutes, it's done.

CHAIRMAN WALLIS: What you mean is -- That's the strategy, but why are you okay?

MR. DiMARZO: Because the natural circulation -- We just said that we have basically done is to show you that that kind of a slug in this kind of a plant is a non-issue in natural situation.

CHAIRMAN WALLIS: You haven't. You've talked about B&W.

MR. DiMARZO: Yes.

CHAIRMAN WALLIS: And you've got to put the CE on the same plane or something so I can understand it.

MR. DiMARZO: Right. That is a correct point.

CHAIRMAN WALLIS: Well, can't you do that? Because otherwise I'm left still not quite understanding. It looks as if a different way of evaluating CE is being used here, and I don't know what to make of it.

Because you've done all this stuff trying to explain to me what you did with B&W.

MR. SCOTT: This is in '94.

CHAIRMAN WALLIS: Yes, but that's history. Now what are you going to do now, and why?

MR. SCOTT: If I went back and revisited the combustion plant, what would I do?

DR. FORD: You'd have to conclude that the CFD, unless you've got some good observations versus theory.

MR. SCOTT: I think in this case I would say, if they're going to do this, if they're going to wait for 20 minutes of natural circulation, I don't need to do a calculation.

CHAIRMAN WALLIS: Why not?

MR. DiMARZO: For the pump. You have to still do a calculation because you have to still do it some certain time after natural circulation.

CHAIRMAN WALLIS: Is this because you get adequate mixing up to 20 minutes is equal to five loop circulations?

MR. SCOTT: I'm not going to have a diluted slug --

CHAIRMAN WALLIS: There won't be a slug anymore.

MR. SCOTT: Right.

CHAIRMAN WALLIS: Well, tell us that. Otherwise, I don't understand why you're reaching a conclusion.

MR. SCOTT: Okay. I see what you're saying. It wasn't obvious that the slug is gone.

CHAIRMAN WALLIS: No. So again, it depends upon the restart strategy. Again, it's up to the operators to do the right thing.

MR. DiMARZO: Although, with this kind of plant, we don't have a problem with natural circulation either. If they start the pump --

CHAIRMAN WALLIS: Yes, but if you had done your pump bump thing. I think you ought to do the pump bump and say what's the conclusion of that? And then say, this is how they avoid it.

And you haven't done that. Are you going to do that, or is this a link which is left unforged?

MR. SCOTT: At the moment I don't have any plans to do any more calculations.

CHAIRMAN WALLIS: So you're going to say you've reached conclusions on B&W plants, and you're going to give us a better argument, perhaps, about why you don't worry about CE, or worried about CE because it was never in the GSI in the first place?

MR. SCOTT: Yes.

MR. ROSENTHAL: Well, I think that it should be -- To say that just because it wasn't in the GSI is a little too narrow. Do we really want to have a written approach?

CHAIRMAN WALLIS: So you're going to have a more cogent argument in front of the full committee?

MR. SCOTT: The argument is that if I don't restart the pumps, we don't think there's a problem. And if I selected the situation, the case, for the BNW machine, which had the worst volumes etcetera.

So if I take another machine, a combustion machine, the Westinghouse machine, that has smaller volumes, maybe has other uncertainties, and I know that I don't start the pump without meeting the criteria, I'm not going to get a reactivity.

CHAIRMAN WALLIS: Well, I would like then to have some sort of a table that says, here are the volumes for B&W, the volumes so you know the number, this is the conclusion I reached from a de matso type analysis for each three, and these ones are nowhere near as bad as B&W because…

MR. DiMARZO: And then we can rule on that very thing.

CHAIRMAN WALLIS: So you're going to do that first before the end of the week? Or whenever it is you appear in front of the committee? Maybe we could take a break and come back and do it.

Well do you see the problem we have? It seems that they should all put on the same -- develop a rationale for one, develop the same rationale for the others.

MR. DiMARZO: The pump is about four meters cubed, give or take. The slug is about 7.4 meters cubed. So when you take that slug of 7.4 meters cubed and you pass it through the pump, at the same rationale that we've had before, that thing is not as smooth. Okay?

CHAIRMAN WALLIS: Okay, that's the real idea.

MR. DiMARZO: The front of that thing is such that we -- it's much milder than, say, Case B we showed you, which wasn't in, and we don't know. So that would be the way we would essentially rationalize that point.

CHAIRMAN WALLIS: You're going to show a picture which shows why you can't get more than 7.4 meters cubed?

MR. DiMARZO: We will show a comparison of that trace versus the trace of Case B, which you have established being the worst possible --

CHAIRMAN WALLIS: Okay. So this is your Case B for C system 80.

MR. DiMARZO: Exactly. And it will be much milder than this.

CHAIRMAN WALLIS: Here are the numbers, and look, the transient is so much more than, because.

MR. DiMARZO: Exactly.

DR. FORD: But if you're basing your argument purely on volume, your slug, the sensitivity in the boron dilution, is that going on a direct volumetric basis?

The dilution rate, which is the critical parameter to go along with the enthalpy. Is it a straight, one-to-one ratio? I mean, it's almost saying that if you --

MR. ROSENTHAL: You'd erode the boron the same for both kinds of plants. Dave, can you answer that?

MR. DIAMOND: For both types of --

DR. FORD: My question essentially was just a straight mathematics one really. For making the argument, the problem is not so much with the Westinghouse combustion purely because the volume of the slug is two times lower.

Does that necessarily mean that the boron dilution rate is necessarily two times --

CHAIRMAN WALLIS: He's going to say it's much, much less. So the volume is the same order of magnitude as the mixing in the pumps, so it really gets mixed.

There really isn't a slug anymore.

MR. DiMARZO: What we have established from Dave's calculation is that you've got to be on the order of a 1000 ppm per second, which is a pump case. We're dealing here probably with damage with or something like that.

CHAIRMAN WALLIS: Okay, but we have to dig these arguments out.

MR. DiMARZO: But we have to put the numbers down on the table.

CHAIRMAN WALLIS: Right. And you're going to do that before you make this presentation before the full committee? This sounds like a rehearsal for a Ph.D. presentation or something.

MR. ROSENTHAL: Why don't we finish the presentation. We'll add up all the IOUs, and then we'll decide --

CHAIRMAN WALLIS: Well, I haven't really seen the presentation yet, because it seems to be coming out in fits and starts. It's not on the slide, it comes out of Marino's mouth.

MR. ROSENTHAL: Yes, what I'm saying is if you let Harold finish, we'll sort of add up all the IOUs and then decided if we can go near the full committee at this time, or need a moment.

CHAIRMAN WALLIS: But he sounds as though, on one hand we're told, take 20 minutes to make a decent presentation, prepare a decent preparation. On the other hand, you're not quite sure if you're ready.

MR. ROSENTHAL: We'll add up all the IOUs.

MR. SCOTT: What I want to do in this slide is to, with this -- This appears to be an actual EPG, not just some guidance type thing, but they -- the question now, of course, is well, how do you know you have natural circulation?

And I was told to wait 20 minutes, or in the early phase 300 minutes, or sometimes 60 minutes.

What evidence is there that you have a natural circulation, so here's a sheet that sort of shows you what symptoms that we look for.

Cold legs, sub-cooling. And the next page in your hand-out --

DR. POWERS: And the fact is that the process by which you go through the CFD and verify you have natural circulation is one that's pretty established.

MR. SCOTT: Yes.

DR. POWERS: I mean, that's one that varies. The operators actually --

MR. SCOTT: I talked to one of the guys at Chattanooga to sort of find out can they run the simulator down there and show me some stuff, because I don't know whether if I ran RELAP or not, I wouldn't know what to look for exactly.

Whether or not I have boron, it's natural circulation that's going to be -- Let me now then jump to, I think the next slide is Westinghouse. Evidently, this is not a full report but this is --

They haven't done any calculations that I could find, but they did do a similar deal for the AP600. Once again, this is the same evaluation report for the AP600 design.

And what I'm trying to say with this slide is what was the basis for accepting the small-break flow with boron dilution scenario? We didn't -- So once again, the volume, as Marino was saying, for this paper design is extremely small, and once again you have to get --

You have a much wider number to shoot for for the boron. Now, that number didn't say critical, it said avoid fuel damage. And I don't know exactly -- I couldn't find what that number meant.

CHAIRMAN WALLIS: What's the normal --

DR. POWERS: No fuel damage, my recollection of AP, no fuel damage meant less than one percent damage.

MR. SCOTT: I didn't put in anywhere the word "no" or "none". You're saying somewhere they define --

DR. POWERS: My recollection now that they deploy, with too many things coming in --

MR. SCOTT: Yes, in this case, I don't know whether this might be 280 calories per gram, 240 calories per gram, 200, I don't know what that number is.

CHAIRMAN WALLIS: Now is this boron, I'm sorry. Boron of 1200 ppm to avoid fuel damage, is that minimum boron?

MR. SCOTT: That's the minimum. Once again, the minimum.

CHAIRMAN WALLIS: But obviously it has to be maintained for some time. I'm astonished with these small volumes that you have to worry about boron at all. And apparently you do.

MR. SCOTT: Well, the paper had a -- I didn't bring the little plot, but it goes along at some high level, it dips down, it doesn't go below 1200, it goes back up, and it didn't seem to be more than few tens of seconds.

MR. DiMARZO: Let me put a statement. If you try to go by natural circulation. You form the slope, and it's 1.2 meters cubed in length. In order to restart natural circulation, you have established that you've got to go through a fast procedure in order to retain the front and the back of the slug sharp.

Once you do that, you reposition the slug somewhere in the tubes, then you start natural circulation --

MR. SCOTT: But I don't have a steam generator in this case. The geometry's completely different. The slug's not forming in the steam generator.

But it's not, there's no off-speed one, if they don't -- The cooling comes through the passive residual heat removal in the containment water.

MR. DiMARZO: I understand that, but the problem is that you are invoking a natural circulation. Is that what you're saying?

MR. SCOTT: Yes, you're right.

MR. DiMARZO: See, if we are dealing with natural circulation, you go through the system. And within the system, we must place the slug up in the steam generator.

As soon as he enters the steam generator of the plenum, this thing doesn't exist anymore. Because steam generators of the plenum are large. So it's going to be lost. At that particular point you've got no front to talk about. This thing is just a dimple.

CHAIRMAN WALLIS: And yet there still is some requirement on the boron.

MR. DiMARZO: Now if you pump it, you have the thing intact, and you're pushing it in. That's another story. But that goes into story previously said. We have to mark one line down.

CHAIRMAN WALLIS: Well can't you quantify what you've been telling us then?

MR. DiMARZO: I can definitely quantify it.

CHAIRMAN WALLIS: And in some kind of --

MR. DiMARZO: Because I know the volume of the steam generator --

CHAIRMAN WALLIS: -- presented way so the logic is clear.

MR. DiMARZO: Clear. We can do that -- We haven't done that, but it's not a problem on the natural circulation side. On the pump side, it's a completely different issue, and we haven't touched that, because that requires much more refined, higher-order analysis.

But as long as we stay in the natural circulation side of things, it's extremely simple and we'll give you a table. It's going to take us some days. That's not an issue.

See what I'm trying to say? I have two cases, pump, no pump. Pump, natural circulation. And that is the major divider. All these pumps and strategy to restart the pump belong to the fact that if you want to do pump here, we need to have tools which we haven't developed.

CHAIRMAN WALLIS: Well, this is quite new. There isn't a problem with the pump start with these other reactors. There's such a small volume, there really isn't any build-up of unborated water.

Stop the pump and the little bit of a transient. Nothing happens of any interest whatsoever.

MR. DiMARZO: We can probably recognize in this one. In the other one, it's -- One point two meters cubed, there's no question. The other is seven meters cubed.

CHAIRMAN WALLIS: Well, why can't you show that?

MR. DiMARZO: Yes, we can. We can do that. Those two are easy.

MR. SCOTT: Now let me go to a non-AP600 Westinghouse, because I thought this would be on your screen, the conditions under which phase we start the pump.

Well, this says it should be started. The implication is it would not be started before. That's only when the outlet thermal couple show 1200 F. So if it's not able to be pressurized, it gets heat transferred.

Or he doesn't have a secondary heat sink, then he's going to try to start the pumps.

CHAIRMAN WALLIS: Greater than 1200 F? That's super-heated steam?

MR. SCOTT: This pressure at the bottom.

PARTICIPANT: This particular procedure is an inadequate floor cooling situation.

MR. SCOTT: Yes.

PARTICIPANT: So you're really out in an extreme --

CHAIRMAN WALLIS: Desperate to get some water.

PARTICIPANT: You've got to try to do something. You're pulling out all stops to keep from severe core damage.

CHAIRMAN WALLIS: So you put in a slug of boron? To make it work?

MR. SCOTT: In general, I was not able to find a Westinghouse -- a similar type, don't start the pump procedures. So in some respects --

CHAIRMAN WALLIS: Well, the thing is, if they did start the pumps, would it make things better or worse?

MR. SCOTT: If they have the unvoided water, or devoided water, they'll get probably the same answer that we got for B&W.

CHAIRMAN WALLIS: Well, where's the boron, then. If it's not in the core, and it's not in the slug, where is it? I'd think it would concentrate in the core if it's not in the slug. It would shut it down.

MR. SCOTT: Remember, in this case in getting this kind of a temperature condition, you're probably going to have a couple of feet, perhaps liquid level, down in the core to start with.

CHAIRMAN WALLIS: Yes, that's right.

MR. SCOTT: So, you're --

CHAIRMAN WALLIS: Pretty rich in boron.

MR. ROSENTHAL: That's not this GR.

PARTICIPANT: That's correct. That's basically why I raised that point.

MR. SCOTT: As Marino said, these are high steam generators. You're saying that there's just a little bit of liquid here that's above us. And any liquid up in here would have run down into the vessel.

So it's only what's in this loop seal that's going to be pumped in if they start the pumps. And I don't know the volume of that. No, I guess --

CHAIRMAN WALLIS: The impression I'm getting is that you did all the work on the BNW. And you went through the sort of logical arguments, such as limiting cases and so on, made a very convincing case.

And then, it was sort of assumed that the other cases are so much more benign, we can make some arguments to make sure everything's -- to convince people it's okay. But that -- Because it seems so trivial, you haven't gone through the logic to make a really convincing case.

MR. DiMARZO: We can make one.

CHAIRMAN WALLIS: So I wonder why you didn't do that, since you knew you were coming up to a formal presentation. It had to be good.

CHAIRMAN WALLIS: You're agreeing to a quantitative error?

MR. ROSENTHAL: Group think error.

CHAIRMAN WALLIS: Group think error. Do you think you're ready? Do you think you're ready to make a case? You will be ready.

MR. ROSENTHAL: Well, yes, as we said, we apologize.

MR. SCOTT: This slide is almost like the one that Professor DiMarzo showed you, where we're seeing the heat fuel enthalpy, with an estimate for the natural circulation is below the range of data for a cladding failure.

But for the restarting of the pump, I'm going to get positive rod damage. But if we restrict pump restart, we don't have to worry about those two.

And again, I think he didn't show this part, but this was sort of the idea we can use to, what we want to call a closed issue.

But there are these procedural constraints on restarting the pump. Where I previously verified that I got rid of the undiluted slug, I won't have a problem.

But we didn't show you any numbers for these other cases.

CHAIRMAN WALLIS: But you don't want to --

MR. SCOTT: I don't know. Do I always have to show you all the details?

CHAIRMAN WALLIS: No, but you have to make a convincing case.

MR. DiMARZO: It's not that difficult. It's very simple. Same logic.

DR. POWERS: Well, I just, once again, I think you have another assumption in all your calculations that requires you to say something about the assumed fuel-management scheme.

MR. SCOTT: Where the assemblies are, where the control rods are, how much positive or negative rod worths there are.

DR. POWERS: I don't know how detailed you have to get. You are probably the better expert than

I, and put upon it is the assumption that you've looked at one fuel entrance.

MR. SCOTT: And if you want to just quickly look at this vent valve. Normally the pressure is high in the downcomer when the pumps are running, therefore these valves are closed.

But if you turn the pumps off and you have a low gut, you're boiling steam in the core, now the pressure inside, above the core is higher, and the steam or water can now go out, down the downcomer, and would then sort of get -- This would dilute any high-pressure injection that's coming in.

But I don't know what those steam flow rates are. The BNW, if you look at their last version of their report on this, they went into some detail about that.

So, you know, if you're really interested I could find those pages for you that would call on that.

DR. POWERS: Well, I've got it here, actually. But actually they were looking at it after the levels had come up. As you're boiling in the core and you have a two-phase mixture occur, and that's a type of static balance, the pressure is higher.

The core's is a vent valve on the

downcomer side. And you will dilute that --

MR. SCOTT: Yes. It would be substantially above the core if I have a lot of water in the core.

MR. DiMARZO: But there is another issue. If you don't have this pressure drop, this mixing to the end, at the end of the day --

MR. SCOTT: Open or closed?

MR. DiMARZO: I think they can, in other words -- so basically, who have the --

MR. ROSENTHAL: In terms of us being ready, I think we've done enough technically for going before the Subcommittee. If he points out that we haven't fully made a cogent story, it might be best to go to the full committee in order to give us time to make that cogent presentation.

I would propose that we not condemn the subcommittee. Having said that, in my own mind, I think of the way the whole program was approached. At one time we were going to do some fancy, thermo-hydraulic fluid flow type calculations, at a time when people relied on point kinetics, simplified physics models, in the typical system.

And the approach that we took was to say, "Wait a minute, can we go do some assisted thermo-hydraulic bounding, and take advantage of this PARCS tool that we've added on."

Which allowed us for the first time to do 3-D space-time analysis. And when we do that, what we see, when we encounter the physics that for a natural circulation type thing where's there time, it looks like the results are reasonably benign.

Of the feedback mechanisms that we knew were there, but then not there. And for the pumped case, the answer's no go. And I think that we can extrapolate that reasonably well with everyone.

So now comes the question of what to do. We surely should write a research confirmation letter that summarizes the work we've done. I believe that we will recommend to NRR that they write a RIS, a regulatory information summary.

What in years past would have been an IM, now it would be RIS, would go out to our licensees. But it wouldn't be mandatory. You know, it's advising of them of what we've done, what we've had done in terms of procedure.

Because the fix here, if anything, is a procedural admonition as distinct from the heart of the plants. We think that at least some of the plant texts already have that in place, and that the event is of sufficiently low frequency, that that's about what we would do for that type of thing.

So I think that our conclusion's okay, and I think we could always tell the story better.

CHAIRMAN WALLIS: Well, it's very important to tell a good story.

MR. ROSENTHAL: Agreed.

CHAIRMAN WALLIS: Especially at a public meeting in front of the full ACRS.

MR. SCOTT: By that you're sort of saying that we were going to sort of -- We didn't have to go into much detail, until the hydraulics side if we had this neutronic cancer.

And it seems like you guys feel that even if we do that, on the neutronic side and have the answer, that we would still need to dot all the I's and cross all the T's on the thermal hydraulic side.

MR. ROSENTHAL: Well, a better story than we've done today. We'll give you --

DR. KRESS: I think you're correct in just looking at these volumes and flow rates. And saying, well, the boron curve is going to be more than that. These are the plants.

What is missing to me is how that translates into the neutronics for the other plants, particularly if they're maybe different fuel schemes, or if the other plants have different feedback mechanisms and different rod worths and so forth.

So that's the part that seems to be missing from the argument, to me. How do you extrapolate these results to other plants and other fuel schemes?

MR. DiMARZO: Accidents occur, and it's orders of magnitude out there, we can just point out that where the curve comes. On the other hand, the curve comes in any proximity to what we have done, then we need to do that --

DR. KRESS: And it's not likely to, looking at those relative volumes you mentioned.

MR. DiMARZO: Absolutely.

MR. ROSENTHAL: Dave?

MR. DIAMOND: Yes, it would seem that the relative volumes preclude having below some of the other vents. As far as the neutronic response, the neutronic response will generally be similar from plant to plant overall.

Pressurized water reactors. Obviously, there are some differences.

MR. DiMARZO: And if we have one of them which is less severe. And I think we can come out with a political statement. On the other hand, if they are compatible, then we have to think a second on what we want. Which is not going to be the case.

DR. KRESS: Yes, well, the other part of that is precluding that the natural convection is no problem for me. But what that does for one fuel scheme.

MR. DIAMOND: That's correct.

DR. KRESS: And yours seems a little bit of a problem, the question there that we would have.

MR. DIAMOND: Absolutely. Even within being designed plants, you have different fuel measures and different types of fuels and different types of fuel-management systems.

DR. KRESS: It's just sort of a little bit of a problem now, and I think we need a better fix on this.

MR. DIAMOND: For example, there are the plants that start off with -- that are having longer cycles and start off with higher boron concentrations that perhaps is a different consideration there, because then the reactivity would be --

CHAIRMAN WALLIS: Is the possibility of fuel-management schemes where you need even more boron worth?

DR. KRESS: And you know, I still have the same concerns that Dana has about the acceptance criteria for high burn-up fuel, in terms of what is a good, acceptable level of allowing the reaction to go to.

And that's -- I don't think you guys are going to fix that problem. But you know we still have that --

MR. ROSENTHAL: Ralph Myers is in Europe as we speak on those issues. By the way, he did tell me that there was a paintbrush curve and some of you had questions on what was it like even at low burn-up. And he said he found in the heat of the moment, was saying that those were data points from which there was plant cracking, and was marked with a similar fuel plan for present dispersal.

CHAIRMAN WALLIS: What do you think Peter?

DR. FORD: I'd have to see -- As far as the -- Are we having a presentation at the --

CHAIRMAN WALLIS: No, I think there are several issues. The first one is should they make a presentation to the full committee. And the other thing is if they do not, what should they be doing.

If indeed they do make a presentation to the full committee, what should they be doing? So first of all --

DR. FORD: Do they have to make a committee presentation?

PARTICIPANT: Well, basically, it's our call, it's our option. It's the subcommittee's option. What do you -- It's on the agenda. You can boil this -- you can beat them up and drag them in there and make a presentation, or you can decide to make a subcommittee chairman make a report, talking about where we are, where we're going with this.

And then you'll collapse --

CHAIRMAN WALLIS: So with just the first question, are they ready for the full committee?

DR. FORD: It struck me that I think they're ready for the -- There's a whole lot of questions still to be answered, but they're not going to be answered even by October, which is when you're talking about.

The difficult question of fuel-management, high burn-up fuel. There are some intrinsic problems where I feel that there's not data to calibrate your simplified structural problem. That that stuff can be put off for October.

You can counter that by saying you're using a bounding curve. Fair enough. Another one is pure presentation style. In terms of, putting the volume, one-half square meters and 40 cubic meters, put that in some rationalization as to why those volumes are important, and compare them one to the other.

That's a paperwork exercise, but you still have to do it. So given those criteria I think it's worthwhile having a presentation.

DR. KRESS: You raised a question that's interesting, and that is the model is basically a transfer function. Then the question is, that has implicit assumptions in it, and do those assumptions get validated by the appropriate experiments of scale, and will the transfer function's applicability depend on flow rates, the relative flow rates and relative volumes.

As to whether or not it's valid or not, and the geometry of mixing volumes, so I think maybe we're dealing with questions we didn't explore enough.

CHAIRMAN WALLIS: My concern is not that there should be a presentation to the full committee. I sort of assumed that this would only be made if it were to lead to a letter which said you have done enough work to put this to rest.

PARTICIPANT: Yes, that's not the case here.

CHAIRMAN WALLIS: I don't think you want to go -- I've been assuming that you do not want to go to the full committee and get a letter which says, "These guys have done a lot of work, we see that within what they've done there's enough that they could put it to rest, but they haven't made the proper case."

And therefore --

DR. FORD: Wouldn't it be useful to them to hear -- they heard our problem.

CHAIRMAN WALLIS: I don't think it'd be really useful to hear non-this committee comments. They might be the same. They should go to the full committee when they're ready.

With the final product that can be approved.

DR. RANSOM: Well, in reading the research plan there's another year on that, which is a substantial amount of effort they're talking about to try to quantify --

CHAIRMAN WALLIS: So this will be an interim meeting report? Then it wouldn't be a closing issue? I thought you wanted to close the issue?

MR. SCOTT: Well, that's the action plan, item one, which says, do what we've done. Then it says, if you determine that is not a problem, skip two, three, four and five. So we're at the point of skipping two, three, four and five, because we showed it wasn't a problem.

But we haven't given you a clear enough evidence, I guess, that it's not a problem. We weren't going to go off and do any experiments. I mean, that was like, maybe, --

DR. RANSOM: You're not going to do that? So that's task five? I think it's task five that you're talking about.

MR. SCOTT: Okay, we'll do that one.

DR. RANSOM: These are the experiments of task five --

MR. SCOTT: We don't have those plans.

DR. RANSOM: In-Vessel Mixing at University of Maryland. CFD calculations in-vessel.

CHAIRMAN WALLIS: I thought I was going to see a document which says we propose, we recommend closing this issue. These are the reasons.

PARTICIPANT: That's right.

CHAIRMAN WALLIS: That's what I thought I was going to see.

PARTICIPANT: Yes, that's what they're planning to do.

CHAIRMAN WALLIS: That's what they're

planning to do? So where is that document?

PARTICIPANT: That was what was provided to me earlier.

CHAIRMAN WALLIS: But this all seems to be in the mind of DiMarzo, or in forms here or there.

DR. KRESS: Well, Jack Leaventhal wrote it.

CHAIRMAN WALLIS: But this is what we recommend closing the issue because of these things?

MR. SCOTT: We haven't prepared that letter yet, and I think what you're saying is normally on these generic safety issues, we have provided the committee with all that information before we asked the full committee to write a report.

So we're sort of not ready to have the full committee write a letter that says.

CHAIRMAN WALLIS: What will the full committee tell you that will be helpful, that we can tell you here? Nothing. So we're wasting their time, unless you've got a final product.

PARTICIPANT: That's my conclusion.

MR. DiMARZO: I mean, we put on the paper enough issues, but.

CHAIRMAN WALLIS: So Dana what do you think?

DR. POWERS: Well, let me begin my comments by saying anybody that uses that as his reference can't be bad. There are lots of comments the Chairman's already made about refining things and getting a written document.

We've got to have a written document. We are surely just not going to write off on a generic issue. We need a written document to study. There are some coherency things that are the limit -- That you get right up to the limit on state of the knowledge on what do we mean by fuel damage?

And is cracking of the CLAD tantamount to fuel damage? Things like that. Well, you don't deal with that. Just fuel damage and things like that. There's this business on fuel schema.

I think you can handle it. I would seriously consider doing another calculation for a different fuel scheme just to see what the sensitivity is. Because I just don't know that it's very sensitive.

It's for the natural circulation case.

MR. DiMARZO: Case A, the malfunction.

DR. POWERS: Yes, the pump case, you know it's bad for fresh fuel. It will be better for high burn-up fuel. What I would plead, as a personal favor of people doing this.

You have gone through this exercise. You have used the tools you have imaginatively. I like arguments -- thermal hydraulic arguments that are tractable that I can understand, whatnot, that don't involve the momentum equation, things like that.

But it's been a struggle to do this, and I think you're going to have other challenges involving fuel and thermal hydraulics coming down the pipe at you, and especially if you go to more innovative kinds of reactor designs.

If you would take an afternoon, and include a slide or a note to the effect of, "If I was not limited by money, what kinds of computational tools would have made doing this job much easier for me, and would be useful in the future."

Because for a lot of reasons, I'd like to see this information. One of which, is that you have to write a research report. The other one is, I worry, especially in the neutronics area, that there is a tendency for the people that make monetary decisions on neutronics to say, "Well, this is a pretty well established field. Let's just live with what capabilities we have, and put our resources into these new high-visibility fields like human factors," or something that's equivalent.

I think there's a good lesson to learn here, on the kinds of tools that you need to have available. And I think it would be an assistance to the committee to see what you think you would like to have.

And maybe we could have some sway with the Commissioner and say, hey, here's some areas that you really ought to think about funding the research to maintain a high level of capability.

In light of the fact that we're going to have unusual thermal-hydraulic and neutronic coupled issues coming down the line in the next few years, if we look at these advanced reactor designs.

And maybe we don't worry too much about gas reactors, because they're so far afield from this. But modern, light water reactors, they're going to be weird, strange.

And you're going to try to get this square peg in that round hole when really the right answer might be to build you a much more flexible tool.

CHAIRMAN WALLIS: I'm surprised that you don't have a tool now. Do you have to go to the de matso type approximate limiting analysis. You can't just put this into some --

DR. POWERS: Yes, but you don't understand, we don't have -- Even if he has done this with computational fluid dynamics, I still would have liked to see what I saw.

CHAIRMAN WALLIS: Oh, I like to see that, but the fact that you're reduced to that, it's the only thing he's got to rely on.

MR. DiMARZO: See, what is the assessment, and the process and so forth. But we do not have that level of access. Therefore, in principle, we know the process.

To take a CFD code and bring it to the same --

CHAIRMAN WALLIS: But my suspicion is that these numbers that you're getting in your limited analysis are way above what's realistic.

MR. DiMARZO: Absolutely.

CHAIRMAN WALLIS: And it would be much better to have some realistic numbers. Because otherwise people think there's a problem when there isn't.

MR. DiMARZO: Absolutely. But the problem is the --

CHAIRMAN WALLIS: Yes, but the problem with going to the limiting analysis is that you raise the spectre of a problem, when probably there really isn't one.

MR. ROSENTHAL: Well, actually, I think I would put it the other way and that's that using the more realistic physics tool for saying that where people thought that there was a problem with the risk factor.

At least we're able to say, wait a minute, in the natural circ. case with feedbacks we don't think there is a problem, and I don't know if we can, what we can do.

But surely there's a conservative approach taken, so that you're beginning to see some of what you spoke about in terms of coupling a modern, 3-D based on kinetics, to a thermal-hydraulic code.

When we run track, we will regularly run track with multiple volumes and core regions, which will be an advantage in part, so we can move on that way. We're trying an experimental, now, coupling of a fuel code into the system.

And we're building the infrastructure to do that. It's also time we revised the thermal hydraulic research plan, because it's been a number of years, and we intended to come back to you before we took out the chisel, but we need that.

And attempt to cut the stone, but we need to get something written down --

CHAIRMAN WALLIS: It's a five-year plan which is already older than five years.

MR. ROSENTHAL: And I'll tell you that I'm challenged by our staff to say, okay, we've been large-break LOCA for a century. And if large-break LOCA went that way, and small-break LOCA got a six-inch LOCA or whatever.

A ten inch LOCA which does depressurize remains, then what would in mean in terms of our code development and experimental program. And they've actually started to write how we might go about changing it.

But that's sort of another meeting. In terms of this meeting, Dr. Wallis, you're absolutely right, we'd like to go to the ACRS and walk away with a letter and so I don't think we're going to be finished.

MR. DiMARZO: Perhaps I have to comment-- so it's not that we don't have that thing. The question was, how can we take advantage of the PARCS situation to reduce that scope of --

CHAIRMAN WALLIS: Well the PARCS part, though, has been done.

DR. RANSOM: Along that line, as a matter of fact, you might look into the conditions under which you can restart a pump. Because you have to have some level of MPSH before you're going to start a pump.

And if the system is depressurized and partly void, I don't think the guidelines would allow you to start a pump.

MR. DiMARZO: But that guideline, that behavior that will restart the pump after you have achieved natural circulation for the certain amount of time, in this particular case it would be one or two.

If you can enforce it. It's a bullet-proof recipe for success, because then you fall back into the natural circulation scenario, which we can solve hands down.

And we're done, basically.

CHAIRMAN WALLIS: Would you like to summarize?

DR. KRESS: One more point I wanted to make, that I don't think I made clearly enough, was on DiMarzo's transfer function. Basic assumption is as a differential volume that goes into the big volume immediately gets mixed.

Now what things could involve a basic assumption? If somehow the differential volume could bypass and not mix, then that may depend on how the flow patterns are, how the geometry is, and I don't know that we discussed that very much, or I don't know how applicable his tests were that showed the curve, how good it did?

Or to the full-scale system. And I'd like to see a little more on this.

MR. DiMARZO: Something about the LOCA.

DR. KRESS: Yes.

MR. DiMARZO: If the slug is small, if the vent is small here, that what you are saying is absolutely a possibility. But then if the thing is small.

DR. KRESS: It's small. Yes, I knew that, and I think some --

MR. DiMARZO: On the other hand it is massive. Then how can it bypass --

DR. KRESS: It can't. You're right. So I -- but I think we need to hear some words back there.

CHAIRMAN WALLIS: Okay, so go back to this assumption that fully mixed and do some more.

MR. DiMARZO: We're putting something that's two, three, four times the volume --

CHAIRMAN WALLIS: Well, not just that. I mean, if you say it's fully mixed in the lower plenum of the steam generator. Your argument is because there are lots of them too.

DR. KRESS: Lots of little jets.

CHAIRMAN WALLIS: Now is there some way in which those jets could go through without mixing and so on. There's probably some element there and there's probably something you could pull out --

MR. DiMARZO: You could go three feet, and you'd have a jet that was probably five or six diameters.

CHAIRMAN WALLIS: Vic, do you have some advice for what these guys should do about coming to the committee?

DR. RANSOM: Well, I looked over the material and I don't think I've heard anything here that changes my conclusion. One, the entire system must be modeled in order to predict the amount of metric pressures that exist, particularly in the B&W, where the vent valves play a role.

And diluting the boron. And also the back-flow, which as you read the system, of course, borated water flows back into the -- the boron enters the steam generator, cold leg and steam generator pump, needs to be considered.

And at a minimum, the system calculation should be used to provide the boundary conditions on a calculation like the E&L, Purdue and PARCS RELAP five type calculations being made.

Which seems one of the most detailed neutronic calculations I guess I've seen, and quite believable. But it's very dependent on the boundary conditions.

If the boundary conditions are not right, you're not going to get the right conclusion. I was a little concerned with the Framatome effort, where they played around with the injection point in the pump.

I think the condensation could cause a steam bubble there, and something really ought to be looked at that, I guess, to see if that's believable.

The other thing, the impression I got that the planned experiment is to result in mixing issues, could be very helpful, provided scaling issues were addressed.

And you must use at least a realistic boron distribution to start out with. Or whatever you use as a simulant for the boron, to eventually find out what the transfer function, if you will, going into the core would be.

And that goes for the temperature distribution initially too. Because you have very cold water over the steam generator side. You've got hot water in the core, and certainly the density difference between those will govern to a large extent, how much recirculation you get in the vent valves.

So it seems like there are a lot of open issues here, and then of course the extension to other types of plants. I would say the same thing applies. You must do a system calculation in general, because of the differences in boiler condenser modes that exist in a U tube type steam generator plant.

And I'd -- the first time I guess I heard anything about CFD codes, but I would see no reason why CFD codes could not be used for the single-phase aspect mixing part of the

CHAIRMAN WALLIS: It's where they are passed. Single-phase?

DR. RANSOM: Yes.

CHAIRMAN WALLIS: They don't break on buoyancy --

DR. RANSOM: But in the core, of course, it's a different story. And in fact there were other factors too, in the core that the V&L core is a parallel channel, so there's no opportunity for mixing between the two.

And you have high-powered regions of the core and low-powered regions and it's known that you get natural circulation even within the core. Which would again mitigate some of the concentrated deborated water basically.

So it seems like there are a lot of open issues to me.

CHAIRMAN WALLIS: But don't you think that if they could show with some limiting analysis that there isn't a problem, that you might not have to go into all these issues?

DR. RANSOM: Well, from what we've heard today, I think for natural circulation that's true. It may turn out that even with pump flows, if you consider the mixing mechanism, they may not be as much of a problem as you think.

CHAIRMAN WALLIS: Which would be very reassuring.

DR. RANSOM: And the other thing is you may, if you look into the conditions under which a pump can be restarted, you may find that, indeed, you would not start it until you had refilled it, completed, and there was some level of pressurization in the system, which may mean you are already well into the natural circulation flow.

DR. KRESS: But the one point that you made. The system where you get dilution running through the vent valve?

DR. RANSOM: Right.

DR. KRESS: That doesn't seem to be part of the bounding calculation. Isn't it -- That would --

DR. RANSOM: Well, the bounding part would be non-recirculation.

DR. KRESS: Neglecting that's a non-conservative symptom.

DR. RANSOM: Right.

DR. KRESS: You think there is some way that , in some way --

DR. RANSOM: Well, to me, to assume no recirculation through the vent valve is equivalent to assuming all the vent valves fail to close. And I think the probability of that is extremely low.

DR. KRESS: I know, but the question is is there enough dilution -- could you add that into your transfer function --

MR. DiMARZO: The point is this. You are activating a pump, which you in this case -- In natural circulation, that's a question.

DR. KRESS: That's where I was going.

CHAIRMAN WALLIS: -- because of the

pressure drop.

MR. DiMARZO: So in natural circulation, I don't think that -- So there might be a well, an ingress of circulation. The question is, what is the transfer time of the slug that we're dealing with, with respect to the potential for mixing of that steam.

But then another question would be more important. For example, what's the geometry of the old chute doing to this incoming slug? Which is a big factor. In other words, how it connected downwards or sideways or whatnot.

So, it's all these things are very important and significant. The question is, do we have again the tools to plan the test. And the tools primarily, are in my opinion, it would have to be something like the CFD.

Even the complexity of the --

CHAIRMAN WALLIS: But your argument is going to be you don't need to do that much.

MR. ROSENTHAL: Are you trying to get the right answer, which would be the ideal world, or are you trying to do --

DR. KRESS: I think you might be able to handle this natural convection dilution.

MR. DiMARZO: Yes, but those things were considered. I can take this cup, in other words that would be the point of the first thing I would look, if I need -- If I was beyond the limit, close, and I know I'm very conservative.

And I start to have to take some other discount. The first thing I would do is to push back. In other words, the deborated HPI through this slug, and leave somewhat smeared as it goes back up into the steam generator.

That's where I would take my discount. Then I would go to what Vic is saying about the internal situation in vessel. That's the same. And then, if I really have to, I will go to the mixing.

CHAIRMAN WALLIS: Yes, well, I think you've got to focus on what you're trying to achieve. You're trying to resolve a GSI.

MR. DiMARZO: Right. So in my case I won't take any of this.

CHAIRMAN WALLIS: My idea is if you did the proper arguments for limiting calculations, and you did it for the other reactor types, and that would probably be perfectly okay to resolve the problem without the pump bump.

Now it may well be that you have enough

resources that you could show also that the pump bump isn't the problem, but it looks as if you're unable to do that today.

And it may be that it's not much of a chance anyway, so maybe you should say, okay, it has to be a procedural solution.

MR. DiMARZO: Exactly.

CHAIRMAN WALLIS: So I think you've got the story. But I haven't heard Vic say that he wants to write a letter based on your presentation in three days' time.

So, it seems to me that we're back to a situation which I don't think is really very good. Where you guys come to us, and we say you're not ready. That shouldn't happen.

My feeling is that rather that Jack suggested if you're not going to the full committee this time, you can go to the full committee next time without coming to us again.

I think that you ought to come to us again. Because there should not be half-baked, half-cooked, not adequate presentations made before the full committee.

MR. DiMARZO: Right.

CHAIRMAN WALLIS: Yes, I -- The arguments should be very clearly laid out. You guys have started off doing the work, you don't spend enough time thinking, how do we make our presentation? How do we make a clear argument? How do we make something that a commissioner can read and be convinced by?

MR. DiMARZO: Exactly.

CHAIRMAN WALLIS: That's what you've got to do. So.

MR. SCOTT: What if we have now four other members -- If this were the same committee, but if you guys extrapolate to the other members and suggest a question they might have.

What you're saying, you don't want me to go --

CHAIRMAN WALLIS: I think there are enough questions that we have, you don't need to hear any more from a non-thermal hydraulic --

MR. SCOTT: Well, I might get those questions in some other meeting.

DR. POWERS: The issues I would worry about with members that are not here are those on operations. You put up slides, and you had a bunch of emergency operations, and things like that.

Three members that are not here have spent a lot of time looking at those. And they're very likely to have questions that have not been posed by this panel.

Now, you're going to ask me, what are those questions? And I would've asked them if I knew what they were.

CHAIRMAN WALLIS: Well, if you like we could perhaps persuade one of those members with operating experience to join this subcommittee next time.

PARTICIPANT: I think that would be a very good idea.

DR. RANSOM: Well, if they have a report to provide, we can provide the report to them and they can look at it.

CHAIRMAN WALLIS: Right, but I think they should be encouraged to invite one of those members.

MR. SCOTT: I think it's also clear that nothing's going to happen as a result of doing this, is there? I mean, we can't act, we already know we can't act yet.

CHAIRMAN WALLIS: Nothing's going to happen as a result of doing what?

MR. SCOTT: -- So that doesn't, no requirements on the --

CHAIRMAN WALLIS: No. That's why it would be good to finish this job. Because it really isn't that big an issue, once it's properly resolved.

DR. RANSOM: Well, it seemed like they're not ready if you leave the pump out. So when you bring in the pumps and the other systems, I don't think it's very conclusive, even though hand waving-wise I think we could argue that there's no problem.

CHAIRMAN WALLIS: Well I'm pretty nervous about hand-waving presentations.

DR. RANSOM: Am I nervous about --

CHAIRMAN WALLIS: I am, very much so.

DR. RANSOM: And I would be too.

CHAIRMAN WALLIS: Dissatisfied with hand-waving.

MR. ROSENTHAL: So let's produce a summary report. Get it to you, and get your prerogative on what you --

CHAIRMAN WALLIS: Well, I think it's more than that. I think that whoever's a responsible manager has to get the team together and get a proper presentation.

MR. ROSENTHAL: Yes sir. And I truly did not mean to waste the subcommittee's time. I thought it was better shared --

CHAIRMAN WALLIS: No, you didn't.

MR. DiMARZO: Basically, it's that the story is viable. Whereas, last time the story was so --

CHAIRMAN WALLIS: Last time it was just -- Say that again, I don't need to say it.

DR. POWERS: No I think this was an extremely valuable point. I don't think you wasted our time at all.

CHAIRMAN WALLIS: I guess I will make a subcommittee report. A very brief --

MR. DiMARZO: For us was very important to determine whether the approach was bad. Because I didn't think it was that sort of a test. Now we have to determine.

CHAIRMAN WALLIS: So I don't think we chastised you. Whoever's keeping track of the progress of this GSI may chastise you, for putting it behind, because they have a deadline.

MR. DiMARZO: And before on the other one would have been a bad year, so they lose no matter what.

DR. POWERS: There's one question on my mind, that you do not need to go to your five-year action.

MR. ROSENTHAL: I would hope that we could resolve this before then.

MR. DiMARZO: But along with what you said, it was going to have to show the whole picture, and then why, to rationalize why we went that way. That is I think very valid. Because it establishes long-term priorities to acquire this kind of tool and so forth.

So this was an opportunity, but unfortunately, depending on which way you want to look at it --

CHAIRMAN WALLIS: Are we ready to break? Anyone have anything further to say? What's the right word? I'll adjourn the meeting.

(Whereupon, the foregoing matter was concluded at 5:02 p.m.)

CERTIFICATE

This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission in the matter of:

Name of Proceeding: Advisory Committee on Reactor Safeguards Thermal Hydraulic Phenomena Subcommittee

Docket Number: N/A

Location: Rockville, Maryland

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.

/s/ Heather Craycraft

Heather Craycraft
Official Reporter
Neal R. Gross & Co., Inc.