Official Transcript of Proceedings ACRST-3186

NUCLEAR REGULATORY COMMISSION

ORIGINAL

Title: Advisory Committee on Reactor Safeguards
Combined Thermal-Hydraulic Phenomena/
Future Plant Design Subcommittee Meeting
OPEN SESSION

PROCESS USING ADAMS
TEMPLATE: ACRS/ACNW-005

Docket Number: (not applicable)

Location: Rockville, Maryland

Date: Friday, February 15, 2002

Work Order No.: NRC-232

Pages 730-828

NEAL R. GROSS AND CO., INC.
Court Reporters and Transcribers
1323 Rhode Island Avenue, N.W.
Washington, D.C. 20005
(202) 234-4433

TR04

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

+ + + + +

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

COMBINED THERMAL-HYDRAULIC PHENOMENA/

FUTURE PLANT DESIGN: SUBCOMMITTEE MEETING

+ + + + +

FRIDAY

FEBRUARY 15, 2002

+ + + + +

ROCKVILLE, MARYLAND

+ + + + +

The Subcommittee met at the Nuclear Regulatory Commission, Two White Flint North, T2B3, 11545 Rockville Pike, at 8:30 a.m., Thomas S. Kress, Chairman, presiding.

COMMITTEE MEMBERS:

THOMAS S. KRESS	Chairman
DANA A. POWERS	Member
VIRGIL SCHROCK	Consultant
WILLIAM J. SHACK	Member
JOHN D. SIEBER	Member
GRAHAM B. WALLIS	Member

STAFF PRESENT:

Paul A. Boehnert

Medhat El-Zeftawy

ALSO PRESENT:

Walton L. Jensen

Jared Wermiel

Ed Throm

Mike Corletti

Ralph Landry

Edward Cummins

Bill Brown

Rick Austin

Jerry Wilson

Milorad Dzodzo

I-N-D-E-X

P R O C E E D I N G S

Time: 8:33 a.m.

CHAIRMAN KRESS: This is a continuation of our Joint Subcommittees on Thermal-Hydraulic Phenomena and Future Reactor Designs, dealing with the subject of Phase 2 review of the AP1000 certification.

I guess we will ask if the members want to have any preliminary thoughts before we start. If not, Ill call on Jared Wermiel to introduce the set.

MR. WERMIEL: This is Jared Wermiel. I am Chief of the Reactor Systems Branch.

This morning we are going to talk about the review that was performed under the Phase 2 of AP1000 of the those computer analysis codes for accidents in transients and for containment analysis.

The first discussion will be with Walt Jensen of my staff. In the Reactor Systems Branch we had a team of my staff review NOTRUMP, LOFTRAN and WCOBRA TRAC, those codes being used for analysis of accidents in transients for AP1000, in order to determine the applicability of these codes for AP1000 utilizing the information that we obtained during the AP600 review and the new information that was provided by Westinghouse as part of this Phase 2 review.

After Walt finishes, Ed Throm from the

Plant Systems Branch will talk about our review of WGOTHIC, the code that is being used for analysis of containment performance for AP1000.

So I'll let Walt go ahead.

MR. JENSEN: I am Walt Jensen, NRC staff, and I am going to talk to you about our review of LOFTRAN and NOTRUMP for AP1000.

(Slide change)

MR. JENSEN: First let me show you some -- the background slide. This details the differences between AP1000 and AP600 for the passive safety systems. We concentrated on the differences between the two plants and how NOTRUMP and LOFTRAN would handle the differences, because we just finished reviewing both of these codes and approving them for AP600.

So a lot of the review we didn't want to repeat again, but as you can see, the makeup tank is a little bit bigger than AP600, but they are the same height but they are fatter. I believe that it was Steve Bajorek in review of the scaling concluded that the CMTs for AP1000 were still within the scale of the CMT test data.

The accumulators are the same size. IRWST is just about the same. They are going to pull a little bit more water in, and the lines going to the reactor system are larger. So they will have more flow.

ADS-1, 2,3 are the same. ADS-4 is larger with a lower line resistance and will remove steam and water a lot faster than they did for AP600 -- or they would for AP600.

(Slide change)

MR. JENSEN: The passive RHR is slightly larger, the same design. The lines going to the passive RHR are larger, larger lines with less flow resistance. So more flow will flow through heat exchangers, and more heat will be removed.

I have some containment data, and Ed Throm will talk about the containment when I'm done.

CHAIRMAN KRESS: On your other slide, the first one --

(Slide change)

MR. JENSEN: This one? All right. Okay.

CHAIRMAN KRESS: Down at the bottom it says the ADS-4 venting is designed to allow for stable IRWST/sump injection during long term cooling. What does that mean?

MR. JENSEN: I guess I can't elaborate on it.

CHAIRMAN KRESS: Does that mean it has a certain capacity to the pump and the sump, and you want to match the drainage out this way, out this thing to it?

MR. JENSEN: This would be for the -- There are check valves that open to the reactor system, once the blowdown was completely finished, and allow the sump water to drain into the reactor system, and the ADS-4 then depressurizing the reactor system completely. Then this is part of the long term cooling process.

This is not modeled in NOTRUMP, but it is modeled in WCOBRA TRAC which is picked up after the NOTRUMP analysis is completed. The NOTRUMP, work stops when the IRWST begins to inject.

CHAIRMAN KRESS: One reason I asked the question is I thought that valve was designed so that you can depressurize at the right rate to get the injections from the other systems during the depressurization, and that this might also be a consideration.

MR. BROWN: I think it's more -- You know, think of it in terms of -- Bill Brown from Westinghouse -- that it probably -- When I hear this, it makes it sound like this really is maintaining the depressurization so that, as you would send the steam out, that essentially you don't repressurize; because if you didn't, then you would have this continual cycling of having to get some injection. You would have to wait for the depressurization to occur through the valve again, if it was undersize, for example, and then have to wait for that whole thing to clear out, and then you get some more injection again, where by the sizing of it and design, you can keep the pressure -- once you depressurize it, keep it down rather than repressurizing and going through a cyclic --

CHAIRMAN KRESS: That fixes the minimum area then?

MR. BROWN: Pardon me?

CHAIRMAN KRESS: That fixes the minimum area.

MR. BROWN: Yes, what you need to do that, yes. Yes.

CHAIRMAN KRESS: Thank you.

(Slide change)

MR. JENSEN: LOFTRAN -- I'll talk about LOFTRAN first. It's probably the easiest. This is an old code that Westinghouse has been using for years to calculate transients, Chapter 15 transients in the reactor system, including steam generator tube rupture and steam line break.

It is used with other codes to evaluate the maximum reactor system pressure, fuel temperature and DNBR that would be experienced for various Chapter 15 transients.

It was approved first after a lengthy review in the mid-eighties and then again for AP600 in 1998. It models the entire reactor system, but it doesn't handle two phase conditions very well except in the pressurizer. Pretty much if two phase occurs, it is assumed to be homogeneous. So one should avoid conditions for which two phase would occur with a LOFTRAN analysis.

(Slide change)

MR. JENSEN: For AP1000, we looked at some of the accidents that might occur. ADS-1, 2 and 3 could be analyzed with the code in a manner similar to a stuck open relief valve, but the analysis stops before any two phase conditions occur, and it's for DNBR only. The inadvertent ADS-4 opening would be done by a LOCA code.

The PRHR is larger and has a higher heat flow -- higher heat flux. The data -- The correlations in the code have been benchmarked and fit to the actual test data, and the data includes --

Excuse me.

CHAIRMAN KRESS: Did they fit that test data by putting a penalty on the area?

MR. JENSEN: This is the -- They use a Rohsenow correlation, I believe, and they fit the exponents in the equation just so they would --

CHAIRMAN KRESS: Oh, they adjusted the correlations.

MR. JENSEN: They adjusted the correlations so it would fit the test data. The test data then includes the conditions that would be encountered in AP1000.

CMT draining -- Let's see. Oh, yes, the split cold legs -- LOFTRAN doesn't directly model the split cold legs for AP1000, but an external model is used to calculate the flow rates for asymmetric cold leg conditions such as a stopped reactor coolant pump, a locked rotor or sheared shaft.

The flows are calculated outside the code and input into LOFTRAN. The models were reviewed for AP600, and we think the same models should be appropriate for AP1000.

MEMBER WALLIS: Well, if LOFTRAN is no good for two phase flow, why is it used for split cold leg?

MR. JENSEN: It can -- As long as the flow is single phase, it can be used for --

MEMBER WALLIS: But it's not, is it?

MR. JENSEN: Pump -- reactor coolant pump trip, and they would evaluate the DNBR, and this would be done before two phase conditions occur.

MEMBER WALLIS: Before two phase conditions?

MR. CORLETTI: Walt, this is Mike Corletti at Westinghouse. Could I just clarify?

I think the split cold leg that you are talking about there is not a LOCA. I think you are talking about the fact that we modeled two cold legs.

MR. JENSEN: Ah, yes. Then again, CMT draining is not expected. So they don't worry about the void --

MEMBER WALLIS: You mean it treats both cold legs as the same?

MR. CORLETTI: Yes, Dr. Wallis.

MR. JENSEN: Treats them as the same.

MEMBER WALLIS: By split, you mean they are different. That split means that there's a different flow in each one. Is that what you mean?

MR. JENSEN: Yes, sir. That's what I meant to say.

CMT draining is not expected, and no void formation is expected to occur in the pressure balance lines. Westinghouse does have a penalty factor here to use in case CMT -- in case the pressure balance lines do become voided, but they don't think this will occur.

The steam generators are larger than AP600, and we were concerned that steam formation might occur in the reactor coolant loops in the steam generator tubes perhaps, in the top of the U-bend or in the CMT pressure balance line in a place that hadn't been reviewed.

So Westinghouse did not submit a steam line break and proposed to do that in Phase 3. So this is open right now, though we have done a preliminary steam line break which shows that no void formation occurs in the system besides the upper head. So this should be resolved fairly easily in Phase 3.

(Slide change)

MEMBER SCHROCK: Did you say 2 or 3?

MR. JENSEN: In Phase 3 Westinghouse will submit the steam line break.

CHAIRMAN KRESS: Now just for my edification, this code, LOFTRAN, looking at it, and it's used for a certain portion of the accident analyses, and you have these considerations that you listed on the previous slide which were things you thought might be things to be concerned about and to look at.

Now you are jumping to a slide that says LOFTRAN is acceptable. My question for my edification is: What went on in between these concerns and reaching this conclusion? Did you take the code calculations that Westinghouse made and looked at them and somehow made judgments about those concerns or did you -- What is the review process that gets you to this point?

MR. JENSEN: Okay, good question. Westinghouse submitted their input manual and their user guidelines to running the code for AP1000. We reviewed those. The code has been benchmarked against SPES data and CMT data and PRHR data.

The scaling of the data was reviewed and found to be appropriate to use for AP1000. We did a RELAP analysis, a steam line break analysis which showed very little cooling.

RELAP entrained a lot of liquid in the steam generator as we blew the steam generator down, and carried a lot of liquid away, where LOFTRAN conservatively assumes only steam that's relieved in a steam line break. The water stays in the steam generator and is available to remove more steam to boil and remove more heat from the reactor.

So this is a conservatism, and then, of course, it had just been reviewed for AP600 and we rely on that review for things that are similar between the two plants.

CHAIRMAN KRESS: I thought you said a few moments ago that the code should not be used for a two phase problem. But now you've just described a problem with two phase in the steam generator.

MR. JENSEN; Yes. I should have added to the components that the code has been designed to model in two phase. I should have added the steam generator secondary side, and the code does handle two phase in steam generator secondary and in the pressurizer, and everywhere else it assumes homogeneous. So I need to thank you.

Well, that's all I have for the LOFTRAN:

CHAIRMAN KRESS: We didn't dwell on that open issue. Would you? We would like to know.

MR. JENSEN; Yes, sure can. The open issue -- Well, I mentioned the steam line break that Westinghouse -- for phase 3.

CHAIRMAN KRESS: Now that's the open issue you just talked about.

MR. JENSEN: But preliminary analysis shows they don't get boiling except in the upper head and the steam generator and the pressurizer, and they calculate a return to power. But we will be looking at that in detail in phase 3.

MEMBER POWERS: You indicated that this particular code had been benchmarked against data from the SPES facility, I believe.

MR. JENSEN: Yes.

MEMBER POWERS: If I developed a substantial masochistic streak and wanted to look at that comparison against the test data, where would I go to find it?

MR. JENSEN: It is in the topical that was submitted for AP600, the final --

MEMBER POWERS: Maybe you could just give me that reference before you leave today.

MR. JENSEN: Okay, I sure will. You're going to have to remind me so I don't forget.

MEMBER POWERS: I think I have most of that someplace.

MR. BOEHNERT: Well, we've got it here, too, I think, if you don't.

MR. JENSEN; I expect you do have it.

MEMBER POWERS: Well, I am reminded of a presentation once when a fellow said I benchmarked my code against some data. We asked him to see that, and the data and the predictions were at right angles. Whereas, he had indeed done what he had said, it's just that the comparison was very poor.

MR. JENSEN: Well, you have already seen this, because you reviewed it for AP600. It's not something you have to review again, I don't think. Do you know?

MR. LANDRY: Dana, Ralph Landry from the staff. That is all in the submittal that was on the LOFTRAN for AP600, and it is in the -- can't remember the WCAP number that it had, but the LOFTRAN submittal had all the RAIs and all the responses to the RAIs.

What Walt is referring to was in RAIs and responses, but that is in the two binders on LOFTRAN for AP600. All those comparisons are shown.

MR. CORLETTI: This is Mike Corletti, Westinghouse. I believe it was in the LOFTRAN validation report. I have two WCAPs here. I'm not precise on which one it is for sure, but it's either WCAP 14234 or WCAP 14307.

MR. LANDRY: I think it was 434, Mike.

MR. BOEHNERT: 234 or 434?

MR. LANDRY: 234.

MEMBER POWERS: Maybe if somebody just scribbled this down, I would have some hope.

MR. JENSEN: Thank you, Mike. Anything else on LOFTRAN?

CHAIRMAN KRESS: So, basically, your conclusion is, its use for AP1000 is okay with the possible exception of this one open issue that you're going to look into further?

MR. JENSEN: Right. That's right.

CHAIRMAN KRESS: Let me understand that open issue and be sure I understand it. LOFTRAN predicts not much voiding, and you got a lot of water left in there to keep the core cool.

MR. JENSEN: No, no. LOFTRAN is single phase. What we are worried about with the things we are looking at with LOFTRAN is DNBR before the rods go in, and maximum pressure for the surges up in the pressurizer. Maybe it's used to input the code to calculate the seal temperature, but there's no core -- that would be calculated with LOFTRAN. That would be with the LOCA code. It's transients, DNBR.

CHAIRMAN KRESS: Okay, but what is it you are worried about with the open issue again?

MR. JENSEN: Yeah, okay. Well, if there

are voids in the system that are calculated in the system, LOFTRAN doesn't separate the voids. It's all homogeneous.

CHAIRMAN KRESS: And you did RELAP calculations that said there might be voids there?

MR. JENSEN: No, I didn't. RELAP didn't calculate any voids.

CHAIRMAN KRESS: Just worried that there might be voids there?

MR. JENSEN: There were no voids in RELAP, but we were worried that the code would not be capable of analyzing the physics of what's going on in the system if voids occurred, except in a limited number of places.

CHAIRMAN KRESS: Okay, I think I understand.

MEMBER SCHROCK: This evidently didn't include a systematic review of the parameter range for the applications of the correlations in the code, or did it? Two are mentioned.

MR. JENSEN; Not systematic, no. No, we didn't do that. We did look at the PRHR heat exchanger correlations and assured ourselves that the data they used was within range. The code was reviewed in a lot more detail for AP600, and I suspect this was done. I don't know.

MEMBER SCHROCK: Thank you.

(Slide change)

MR. JENSEN: NOTRUMP: Now NOTRUMP -- It's a small break LOCA code, and it's used to calculate the inventory in the core and whether the core becomes uncovered or not. And if it does become uncovered, Westinghouse's model, small break model, includes the SB LOCTA code that's used to calculate peak cladding temperature.

Westinghouse is hopeful that there will be no core uncovery calculated by NOTRUMP, and so they won't be in need for a core heatup calculation. But again, this was -- The NOTRUMP code was -- It's an old code, and it was approved by the staff for operating plants after a long and rigorous review in 1985, and then again for AP600.

It uses five conservation equations with slip models to evaluate the steam and the water velocities. It does not -- The present model doesn't include momentum flux for area and density changes.

Westinghouse did a study --

MEMBER WALLIS: Those are the ones that are usually controversial. So they just leave them out?

MR. JENSEN: Well, yes. It also made the code -- Apparently, it made the code run unstably.

MEMBER WALLIS; Easier to run. It makes it easier to run. No, really. You can do that. You can make the code unstable with momentum flux term.

MR. JENSEN: Yes. Now they did a sensitivity study for AP600 and concluded that the momentum flux had very low effect except for ADS-4, because of the high velocity effect.

CHAIRMAN KRESS: And they did something to compensate for not having those. Is that where they artificially reduced the water level?

MR. JENSEN: Yes, sir, they did that, and they also talked about adding a resistance, extra resistance in the IRWST line.

CHAIRMAN KRESS: To account for the what would have happened if you had momentum.

MR. JENSEN: Right, and they propose to do a similar thing with the resistance for AP1000.

CHAIRMAN KRESS: But not do the penalty on the head of the water level in the IRWST? To do the resistance instead?

MR. JENSEN: That is true, to do the resistance and not the water level penalty.

CHAIRMAN KRESS: And that resistance would be determined by comparing with SPES data?

MR. JENSEN: This was determined for OSU, I believe, in this case.

CHAIRMAN KRESS: OSU data? Okay, OSU data.

MR. JENSEN: And then I think they added some additional resistance for conservatism. Now would that same thing be appropriate for AP1000? Well, that's kind of tied up in the overall --

CHAIRMAN KRESS: That's the question, isn't it?

MR. JENSEN: Yes, that's the question. We have a number of issues involving ADS-4 that need to be worked out.

(Slide change)

MR. JENSEN: Well, we made a RELAP model for AP1000, and we tried to make it as close as we could, to use the same assumptions that NOTRUMP was using, so we could compare the two codes, one against the other.

There's a single failure. One of the ADS-1 lines had assumed ANS plus 20 percent, and the containment back pressure is set to atmospheric, just like in NOTRUMP.

The first thing we did, we got one of the old AP600 runs, and yes, it does have a lot of hash in there.

CHAIRMAN KRESS: Is that numerical or is it real?

MR. JENSEN: Numerical, mostly on the back part.

MEMBER WALLIS: We don't have any real.

MR. JENSEN: Some of it may be real, but I think this is numerical, and particularly it's caused by the steam properties at low pressure, and they were doing -- The code had trouble converging.

This is an older version of the code, too. It's 2.3.3 gamma, and they have recently released a 3.3 beta to the count numbers, and that's what we used for AP1000, but this is an old run for the older plant.

What you see is that --

CHAIRMAN KRESS: This is like inducing a LOCA by opening up ADS-1?

MR. JENSEN: Yes, that's the way it is. ADS-1 sticks open.

CHAIRMAN KRESS: Well, then does the depressurization continue through ADS-2, 3, and 4?

MR. JENSEN: Yes, sir. As I said, this is predicated on the draining of the CMT.

CHAIRMAN KRESS: Draining of the CMT. Okay.

MR. JENSEN: And then, of course, the accumulators inject. CMT injects, and things are pretty stable until ADS-4 opens, and that causes the void fraction in the core to soar. That's this big soaring in the void fraction.

CHAIRMAN KRESS: I see.

MR. JENSEN: And then the peak is turned around the IRWST injection, which continues to inject and then drops the void fraction to a fairly low level which, unfortunately, in this version of the code kind of jumps around.

MEMBER SCHROCK: This code to code variation might give you a warm feeling, but don't you need some demonstration through data as well? Are there some data for this type of accident?

MR. JENSEN: Well, yes, AP600. Of course, there was the staff test and OSU and ROSA test, and RELAP was benchmarked against numerous of those tests back in the AP600 review.

MEMBER SCHROCK: Well, benchmarked could mean a lot of different things, I suppose, in terms of the data compared with the prediction. But have you looked again at how well RELAP did for this particular transient in order to satisfy yourself that using it as a comparison now against NOTRUMP provides useful insight?

MR. JENSEN: Yes, I think it did a pretty good job on stuck open ADS-1. Well, maybe -- I don't remember whether they did a 1 or what, but they did a stuck open ADS, I'm pretty sure, out of the pressurizer. I think it did a pretty good job.

It had some trouble on some of the OSU beyond design basis runs, and it had problems with ADS-4 entrainment. One of the reports, I believe, thought that there was too much entrainment in ADS-4, and another report thought there was too little entrainment. But, yes, it has the problem.

So we are not going to review AP1000 based on what RELAP says. It helps us to understand what's going on, so we get an idea about the conditions in the plant and helps us to know what questions to ask to Westinghouse. But I wouldn't put a great deal of confidence in what RELAP predicts, other than it did do a pretty good job on a lot of these test results.

CHAIRMAN KRESS: Do you have a similar curve for -- calculated by NOTRUMP, just to see what they look like?

MR. JENSEN: No, not -- Well, what I

wanted to show you now was for the AP1000.

(Slide change)

MR. JENSEN: As you see, the hash has gone away. I do have some comparisons with NOTRUMP I'm going to show you in a minute.

MEMBER WALLIS: You are going to show comparisons with the sort of map that Dr. deMarzo showed us yesterday of the actual level of the liquid in the core at the critical time?

MR. JENSEN: What I was looking at here mostly was the void fraction. But, yes --

MEMBER WALLIS: Inventory versus time or something like that. She showed us a plot of total amount of liquid versus time, and depending on what you assumed about entrainment, you got different answers.

MR. JENSEN: Right. Okay. Well, of course, the minimum liquid in the core, if you looked at the collapsed core level, would occur when the void fraction is the highest. That's right before the IRWST injects.

CHAIRMAN KRESS: What exactly do you mean by void fraction here? This is in the core?

MR. JENSEN: This is the top node of the core.

CHAIRMAN KRESS: So the top node of the core. Okay.

MR. JENSEN: Now RELAP has nine nodes, I believe, in the core.

CHAIRMAN KRESS: But it's the top node you are dealing with.

MR. JENSEN: Right.

MEMBER WALLIS: So that would mean here that the top node void fraction is almost one in this.

MR. JENSEN: That is true.

MEMBER WALLIS: The question I would ask is what's it in the node below that, and so on?

MR. JENSEN: Right. I didn't bring it. It's lower in the node below it.

MEMBER WALLIS: It is.

MR. JENSEN: It finally gets down to -- IN the bottom of the core, it gets down to a void fraction of around 50 percent in this tail that comes out.

MEMBER WALLIS: Well, the collapsed level is going to be less than half of this that you've got here, if the minimum void is 50 percent.

MR. JENSEN: The collapsed level is probably around 30 percent. I did look at some of the collapsed levels, and it's around 30 -- 33 percent, I think. So it's pretty low, but the pressure is low, and the steam takes up a lot of room.

So if you just looked at the quality, you looked at the mass ratio, and it would be -- mass ratio would be -- It would look a lot better. It would be like 30 percent or 50 percent.

CHAIRMAN KRESS: But this is telling me that with AP1000 for the same accident sequence for AP600 that your top node of the core is pretty well uncovered or pretty high void in it?

MR. JENSEN: It has a lot of voiding.

CHAIRMAN KRESS: It stays there quite a while?

MR. JENSEN: Yes, sir. That's exactly what I wanted to show you, that there's more voiding than AP600, and the voids are higher, and they stay there high a long time.

CHAIRMAN KRESS: For this particular sequence?

MR. JENSEN: Right, and other small break LOCAs look very much like this, because actually, once the CMTs start to drain and ADS opens, they all look pretty much the same. Then they are all really controlled by the ADS, especially ADS-4, because it's just so big compared to these little breaks. But they all look pretty much the same.

MEMBER SCHROCK: You have containment pressure as a parameter on the slide. Does containment pressure play any role here?

MR. JENSEN: Yes, it would.

MEMBER SCHROCK: Isn't it critical flow through the break throughout this time period?

MR. JENSEN: No, it goes down to subcritical flow.

MEMBER SCHROCK; In 4000 seconds?

MR. JENSEN: Yes. It's about the time that the IRWST begins to inject that the flow drops to subcritical. If the pressure is higher in the containment -- Westinghouse in fact did some sensitivity studies, and they got substantially less voiding when they used a higher containment pressure.

Of course, they used a constant containment pressure, I believe, and if one was going to take credit for containment pressure being higher, one would have to calculate it. It would probably still be pretty low until ADS-4 fired off. ADS-1, 2 and 3 go down into the IRWST and get quenched, and only when ADS-4 goes off then is there a large flow into the containment.

So it would be somewhat more work and cause probably some iterations between codes to take credit for the containment pressure.

CHAIRMAN KRESS: So what is it about the AP1000 that makes this difference between it and 600? Is it because your flow out to ADS-4 is greater, and it can't be made up as fast by the passive systems that are feeding water into it?

MR. JENSEN: That's part of it, and probably a lot that -- mostly, it's the power. The power is bigger. The power density is higher.

CHAIRMAN KRESS: So it's pouring out more steam.

MR. JENSEN: More steam. More steam is coming out. The accumulator is the same size. CMT is just a little bit bigger, and so more reliance is being placed on the ADS-4 to depressurize the plant and get injection from the IRWST.

MR. CORLETTI: This is Mike Corletti from Westinghouse, Walt. Could I just --

MR. JENSEN: Oh, please do.

MR. CORLETTI: The main focus of the phase 2 was really looking at the code applicability and the performance of the code and how -- are the phenomena similar between the two plants.

I think what we are going to find -- What we did is a preliminary set of analyses with bounding power shapes. I think what we probably find -- I don't think Walt really focused on is it safe -- the safety of the plant was not -- They weren't really making judgments on that.

CHAIRMAN KRESS: That's not the issue here. Just looking to the applicability.

MR. CORLETTI; Right. And I think what we'll see for our safety analysis that we present in the design control document you are going to see ----- With the AP1000 specific power shapes and some of the other specifics that we've put in, you are going to see voids probably not quite this high as presented here. But that will be all reviewed as part of the phase 3 design certification.

CHAIRMAN KRESS: Okay. That's a good clarification.

(Slide change)

MR. JENSEN: Now here I do have a comparison between NOTRUMP and RELAP, and this is for a two inch cold leg break. This is actually the only --

MR. BOEHNERT: Could you take that other slide off, Walt? It's hard to see.

MR. JENSEN: Oh, I'm sorry. Sure. And should I turn the projector off?

MR. BOEHNERT: Yes. Thank you.

MR. JENSEN: All right.

CHAIRMAN KRESS: Now this would be almost like that ADS-1 case you just showed?

MR. JENSEN: They look very similar.

CHAIRMAN KRESS: Very similar

MR. JENSEN: This break size is the only break that we really can compare to, this two-inch break, with NOTRUMP. There were a number of analyses done by Westinghouse about a year ago, and they were with some old assumptions for AP1000. So only recently have they redone this one. So we are comparing the RELAP analysis.

They thought this would be the best to compare with RELAP. But this is the only one we have right now for comparison. So what we'll get for the other breaks remains to be seen.

So as you look down this table, you see there are some differences. The first thing you see is the reactor trip. We tripped ours on a overpressure delta T at 9.4 seconds, and Westinghouse has tripped a lot later.

They wait until they get a lower pressure signal in the pressurizer before they trip, and that occurred a little bit later. I guess they don't take credit for the overpressure delta T.

The safeguard signal came in about the same time. This would be on low pressurizer pressure. Reactor coolant pumps tripped on the safeguard signal about the same time, but we are using a 15 second time delay that was in AP600, because that then is just a modification of the old AP600 that we used for that plant. It's probably about the biggest RELAP deck ever made.

So it looks like we got some different delay times that we are using between us and Westinghouse. So we're going to need to work out some of these differences.

MEMBER SCHROCK: This table is AP1000?

MR. JENSEN: This is all AP1000. I'm sorry, sir. Yes.

MEMBER SCHROCK: Do you have a complementary table for AP600?

MR. JENSEN: No, sir, I don't. I didn't want to spend much time on AP600, because we had already done that one.

The CMTs begin to drain a little sooner in this NOTRUMP analysis. Accumulator injects sooner, and then look at ADS-1. It's really a lot faster than RELAP.

ADS is based on the core make-up tank volume. So apparently we are losing more core make-up tank volume or CMT volume, losing it faster in NOTRUMP than in RELAP.

Then we got the high void fraction, 90 percent. It even, in fact, goes up to 95 percent at 3660 seconds when the IRWST injects.

So everything -- We've compared a number of the parameters, the ADS-1, 2, 3, and 4 flow, CMT injection, and they all looked very similar except for a shift, because NOTRUMP is doing everything faster. So why is NOTRUMP boiling down faster than RELAP?

MEMBER SCHROCK: Was that supposed to be best estimate? Isn't NOTRUMP the conservative code?

MR.JENSEN: That is true. That is true. But part of it is the way the plant is described, and it looked like to us it was the break flow model.

This is what RELAP calculates for the break flow. This decompression difference occurred before any of the ADS started to inject. The only thing being lost when the system was compressed was coming out of the break.

So what you see here looks pretty much a conventional plant for a small break LOCA. There is a subcooled blowdown.

CHAIRMAN KRESS: Now this is the NOTRUMP here?

MR. JENSEN: Excuse me. This is RELAP.

CHAIRMAN KRESS: This is RELAP?

MR. JENSEN: This is RELAP. This is where RELAP says the break flow is. I'm going to show you the comparison in a minute, and I wished I had -- I should have written RELAP on here.

So we have a subcooled blowdown where RELAP is using the Henry Fauske correlation, and then we have a saturated blowdown, which is this flat part, and then a two phase blowdown where it comes down. ADS is open here, and sludge, water and steam are coming out of the break at this time.

So this is what RELAP gets. Now what does NOTRUMP do?

(Slide change)

MR. JENSEN: I got a lot of things on here. The solid line is AP600. It just happened to be on this slide. I wish it wasn't. This is a Westinghouse figure, but the dashed line is NOTRUMP for AP1000. So that's what we want to look at, this dashed line for AP1000. You see it?

They, too, got the subcooled blowdown. They used the Zaloudek correlation, which gives a -- It is conservative, and it gives a higher flow than RELAP does in the subcooled blowdown.

Then they have the flat saturated part. But then they get the big spike of water coming out of the break that RELAP doesn't calculate. All right. Now what it looked like to us that caused this was the downcomer description in the codes.

RELAP divides the downcomer into eight radial nodes between the downcomer and the core barrel. So the eight radial nodes of the CMT line are in individual nodes. I had a figure that said Westinghouse Proprietary. So I didn't bring it.

Each pole leg is a individual node. So it's a highly segmented downcomer. So when the break occurs in the cold leg, the flow reverses in that section of the downcomer, but the CMT water is free to continue the flow down to its segment into the lower plenum and up into the core.

Now Westinghouse does not segment their downcomer. So they have it in a single segment like a pipe with -- I think they have maybe three axial nodes.

So what happens in NOTRUMP when the CMTs eject, the whole downcomer, being a one-dimensional pipe, tends to flow the break and carries the cold CMT water with it. When this cold subcooled water comes to the break, the critical flow model that is their Zaloudek correlation for a subcooled blowdown, just blows out a lot of water out of the system.

So this is why they are losing water, we believe, faster than we are. I suppose it's conservative to do this, to lose water faster. This is why we are different, I think.

MEMBER SCHROCK: This flow rate does not include the ADS flows. It's the flow through the break?

MR. JENSEN: This is the break flow.

MEMBER WALLIS: So we get a difference of something like 200 pounds per second for about 200 seconds. That's 40,000 pounds of water. Now is that important compared with the inventory of the system?

MR. JENSEN: I think it's a lot of the CMT water.

MEMBER WALLIS: How much water is in the CMTs?

CHAIRMAN KRESS: 2500.

MEMBER WALLIS: Twenty-five?

MR. CORLETTI: There's 5000 cubic feet of core makeup tank.

MEMBER WALLIS: How many pounds is that?

MR. CORLETTI: Times 62.

MEMBER WALLIS: So it's hundreds of thousands of pounds of water.

MR. JENSEN: So let me go back to my comparison slide again.

(Slide change)

MR. JENSEN: So we got very similar answers to NOTRUMP for this break. The void fractions we got were slightly higher, but they were pretty high in NOTRUMP, too.

We did some other breaks, too, and we did a pressure balance line and, of course, we did ADS-1.

MEMBER WALLIS: I think what you are saying is the details are very different, but the overall picture, when you look at the whole thing, is about the same. Now the timing of events is different from RELAP and Westinghouse, and the amount of water you get in and out at various times is quite different, but when you look at the overall picture at the end of things, result is about the same. Isn't that what is happening?

MR. JENSEN: That is true, and the details are similar except for the break flow. I wanted to tell you, too, we did a double-ended DVI line break, and we got a little bit of core uncovery with RELAP.

RELAP had a hot channel in it -- hot pin. It didn't have a hot channel. It had a hot pin, and it calculated a peak cladding temperature of about 400 degrees Fahrenheit. So it's not anything -- not a big core uncovery, but it dipped down at the core a little bit in RELAP, and we don't have an up to date DVI line break from NOTRUMP. So we don't know what that is.

Then again, we're not going to approve the plant or disapprove the plant based on RELAP, because we are not sure we believe it.

MEMBER WALLIS: Well, I don't know. You have to use some sort of judgment here. If RELAP is predicting disaster, then you really want to know why there is no disaster.

MR. JENSEN: That's true. It has been benchmarked against the data, and we have some confidence in it, but we think it may be a little weak for the entrainment in the ADS-4 line and the hotleg. That's the same trouble that we're having with NOTRUMP, and we'll have to iron in phase 3.

MEMBER WALLIS; You didn't show any comparisons between your predictions and, say, something like the APEX facility or something that would give some confidence that you were not too far from reality with your predictions?

MR. JENSEN: Well, like with LOFTRAN, that was all done in great detail for AP600, and I could give you some references for that, too, if you would like.

CHAIRMAN KRESS: Now I recall those comparisons for AP600. They had these three categories, good, better and best, or something like that. It depends on where the calculations fit within the uncertainty band on the data.

Best I remember, for most of the accident tests run, they fell within the uncertainty bands of the data, which gave me some confidence that they were doing pretty good.

MR. JENSEN: It looked pretty good. It did.

MEMBER WALLIS: But then if I look at what you just showed us for the break, the AP1000/AP600 curves are very different. We don't have any modeling of AP1000 by something like APEX. So we have to take it on faith that --

MR. CORLETTI: Dr. Wallis, this is Mike Corletti. We had hoped that our scaling was really showing that APEX was scaled for AP1000. So that was the basis for using the same validation.

MEMBER WALLIS: I don't quite know what you mean by scaling here. They are certainly not getting the same curves. Look at that curve you showed us just now with the flow right out the break versus time. It's certainly not the same scenario.

MR. JENSEN: This one?

MEMBER WALLIS: No, no, no, no, the one with RELAP 5, AP600, AP1000, two-inch 49, whatever that is.

MR. BOEHNERT: This one right here.

MR. JENSEN: The break flow.

MEMBER WALLIS: And we got three curves. RELAP5 seems to be absolutely fascinated with 200 and stays along there. Is that what the crosses mean?

MR. JENSEN: Yes, it does. It stays there, because the -- Then the flow to the break is saturated. It's saturated water in there. I mean, it just kind of sits --

MEMBER WALLIS: If I look at these two curves, I'd say, well, AP600 and AP1000 don't have the same response, do they?

MR. JENSEN: No, they don't.

MEMBER WALLIS: Quite different. So what's being scaled by something like APEX? Is the

APEX response like the 600 or like the 1000 or something else entirely? I don't know.

MR. JENSEN: Of course, the difference in the break is the same size for both AP600 and AP1000, and with the break the same size --

MEMBER WALLIS: Ah. Not the same scaled size. Is that what it is?

MR. JENSEN: No, the break is not scaled in this. The break is a two-inch break.

MEMBER WALLIS: It's not a scaled break. So you shouldn't compare based on the same size, but we should perhaps compare some other break size which is properly scaled between 600 and 1000? That's probably the trouble.

MR. CORLETTI: Dr. Wallis, in our report that we submitted that was precisely what we showed, that it appeared that the larger break -- To get equivalent performance, you needed a little bit larger break for AP1000.

Really, what we saw was really a time shift for breaks of the same size. So that seemed to be consistent with -- That led us again to a judgment that the plants really do operate from a scale basis the same.

MR. CUMMINS: Dr. Wallis, Ed Cummins.

To me, those curves look alike, with the AP1000's spike just delayed. If you just translate it to the right, then they look very similar.

MEMBER WALLIS: I don't know quite what you mean by similar.

MR. CUMMINS: On AP600 we also got a spike. It was just earlier in time.

MEMBER WALLIS: And Everest looks like Mt. Washington, if you take two foot out and put them close together.

MR. CUMMINS: They look a lot closer to RELAP.

MEMBER WALLIS: This is not very -- I think the real thing is that, if you scaled the break, you'll be able to show a much better comparison. That would be more meaningful than maybe trying to wring something out of this picture which is not very meaningful.

CHAIRMAN KRESS: And when you scale the break, the size that you scale it to is going to be different, depending on which one of those periods you are in, because one of them, you are going out critical flow, and the other one going out subcooled, and you will get a different scaling ratio for the break size.

So you have to be careful with just saying how you scale it. But I agree with you. If he scaled it to the break size for the different periods on that curve, why you will probably get similar.

MEMBER WALLIS: I think we concluded for AP600 that you got all these bathtubs indirectly and, depending on some rather small changes, it can make a difference whether this bathtub goes in before that one and all that. But at the end of the day, if you look at whether or not you get uncovery that period, it doesn't matter too much what you did before.

That's perhaps where the focus should be in these studies, whether or not you get uncovery and how sensitive it is to where all these different things are happening before, which really don't really make that much difference at the end state.

MR. BROWN: All right. Bill Brown. I think what we'll find is that if you take all those and get -- Once you get ADS, I think these will all look the same. I think that you are going to see some differences up front a little bit, but once you get ADS --

MEMBER WALLIS: Once you get ADS-4.

MR. BROWN: Exactly. I think they basically will look very, very similar and will converge to that.

MEMBER WALLIS: Well, the idea of ADS --

MR. BROWN: Is to turn it all into -- a little break into a bigger break and all look the same.

MEMBER WALLIS: What happened before doesn't matter.

MR. BROWN: Right. Right. All the history is lost.

(Slide change)

MR. JENSEN: Now these are some of the components we looked at in the AP1000 review. The accumulators are the same size. ADS1, 2 and 3 are the same size, and the CMT -- they are the same height and fatter, and these were all compared to test data in AP600. So --

CHAIRMAN KRESS: Is each CMT 23 percent more volume or is that the total for the two of them?

MEMBER WALLIS: Probably both.

MR. JENSEN: II think each one would be 24 percent more volume. Now the PRHR heat exchanger is 22 percent larger, but because the inlet and exit paths have a reduced resistance, it's designed to remove 72 percent more heat.

Now NOTRUMP has some problems with high

heat flow in a PRHR heat exchanger. I told you how for LOFTRAN that they had modified the exponents in the Rohsenow correlation to fit the test data. NOTRUMP uses the Tome correlation for boiling in the IRWST, and Westinghouse didn't fit the X points in the T correlation.

MEMBER WALLIS: Pretty nostalgic. This has worked on in the late fifties.

MR. JENSEN: Probably so.

CHAIRMAN KRESS: It modified the exponent or the coefficient?

MR. JENSEN: I don't remember what this -- Probably both of them, but they refit the curves. Now so Tome is nonconservative in comparison to the PRHR test data at high heat flows. So Westinghouse has benchmarked against a 1.5 foot per second flow rate in the tubes.

So then the question is what is the flow rate in the PRHR heat exchanger tubes, and is it greater or less than 1.5 feet per second? So this is another RELAP calculation.

So anyway, the flow rate, we found, is considerably higher than 1.5 feet per second. So what did they do with NOTRUMP in this area where the code is stated not to be completely out?

Well, PRHR heat exchanger heat flow is just a medium in points, and it probably doesn't have a great deal of significance for a small break LOCA, and Westinghouse has even done a preliminary study that they reduced the heat transfer area by 50 percent, and it made very little difference in the course of the LOCA. But they are going to qualify their assumptions during phase 3 for the PRHR heat exchanger flow.

CHAIRMAN KRESS: Now this PRHR heat exchanger is mostly there for the long term cooling?

MR. CORLETTI: No. A PRHR heat exchanger is primarily there for transient. So it's there on a LOCA event, but it really was not the sizing basis. What we've seen in most of the LOCAs is, once you depressurize, go two phase, it really does not become a big factor in the transient behavior.

CHAIRMAN KRESS: This is one place where you have a pump, and it's an active system?

MR. CORLETTI: No. This a passive RHR heat exchanger. It sits in the refueling water storage tank.

CHAIRMAN KRESS: It's that C-shaped thing?

MR. CORLETTI: Yes.

CHAIRMAN KRESS: It's the water flowing

to the inside of the tubes?

MR. CORLETTI: Right. It's by natural circulation.

CHAIRMAN KRESS: By natural circulation.

MR. CORLETTI: Yes. And it's really a sizing basis. It's for transients like loss of normal feed, feedwater line break, those sort of events. But it is modeled in NOTRUMP in the LOCA, and it doesn't have much effect unless you have a very, very small break.

CHAIRMAN KRESS: What's the heatsink on that when you get outside the IRWST?

MR. CORLETTI: The refueling water storage tank, and if it would -- for a long transient would heat up and boil, steam would condense on the containment shell, and we have it return back to the refueling water storage tank. So it essentially can stay as a heatsink --

MR. CUMMINS: Using containment then, basically.

MEMBER WALLIS: I wonder if we could move on to the bottom line?

MR. JENSEN: The bottom line? Sure, the bottom line.

MEMBER WALLIS: This is a real bottom

line? This hasn't been manipulated by the accountants in some way?

(Slide change)

MR. JENSEN: This is where we are right now with phase 2. So we think NOTRUMP is pretty good except for three areas, and maybe just two, and the big one is the liquid entrainment from the core into the upper plenum and out the hotleg and out ADS-4.

Westinghouse proposes in phase 3 to benchmark NOTRUMP against the WCOBRA/TRAC.

MEMBER WALLIS: I don't see how that works. I mean, you say one code against another. The physics is wrong. How is that going to help you?

MR. JENSEN: Okay. Then they are going to benchmark WCOBRA/TRAC against test data.

MEMBER WALLIS: Ah, they are going to do that. That's going to be essential.

MR. JENSEN: Finding the right test data may be where the difficulty lies.

MEMBER WALLIS: You're going to hold the line there?

MR. CUMMINS: Yes.

MEMBER WALLIS: Not to say it remains an issue, but supplemental verification will be performed or something.

MR. WERMIEL: Ultimately, Dr. Wallis -- This is Jared Wermiel. Ultimately, we will need some confirmation either through test data or some data that we can all agree that it is valid that, indeed, if they do do a sensitivity study on this phenomena, that the sensitivity is telling us the right thing, and ultimately it's an answer that we can rely on.

It will also depend in large measure on some qualitative arguments about how significant this entrainment -- You've heard argument yesterday. How significant really is this issue? We are still not sure, and that will be a source of continual discussion during the phase 3 review.

MEMBER WALLIS: Yes. Thank you very much.

MR. JENSEN: Okay. then the second one is the PRHR heat exchanger model, which is open, but we don't think it's going to have much effect.

Then finally, we have looked at --

MEMBER WALLIS: I'm sorry. Proposes to reduce the heat transfer area -- that's simply -- That's in the numerics. They are going to say, well, if you don't like it, we'll just assume it's half as big, and that's conservative. Is that -- It's not actually physically reducing?

MR. JENSEN: Right. Hopefully.

MR. CUMMINS: That's right.

MR. JENSEN: And they will look at the test data to see.

MEMBER WALLIS: Let's just cut it in half.

MR. JENSEN: Oh, I see what you mean. Excuse me. Well, us analysts, we don't deal with hardware very much. In fact, we sometimes forget about that it's actually a plant that's going to look like this. It's just a bunch of numbers.

All right. Then lastly, we've looked at one break size, the two inch cold leg break, and there was no core uncovery. But in the course of phase 3 we are going to be looking at the entrainment out of ADS-4, which will affect what is going on in the core, and we'll be looking at a lot of other break sizes.

So it's very likely that core uncovery will be calculated.

MEMBER WALLIS: So this statement, only a limited number of breaks have been analyzed -- that means by you or by Westinghouse?

MR. JENSEN: By Westinghouse.

MR. WERMIEL: By Westinghouse.

MEMBER WALLIS: Well, you said you are going to be looking at it. Does that mean you are going to be doing more analysis?

MR. JENSEN: We will do more analysis. We have done -- looked at several break sizes already, and we got a small amount of core uncovery for one.

Westinghouse is going to look at some more, but I think the final runs are going to be -- have to be after the ADS entrainment issue is solved. So will there be core uncovery? I don't know, but the SB LOCTA code and the NOTRUMP code really haven't been looked at for core uncovery in the passive plants.

There's a transition boiling model in NOTRUMP that we didn't look at for AP600, because no core uncovery was calculated, and the SB LOCTA code -- I'll look back to see when that was reviewed last. I think we looked at it -- It was LOCTA4 back then, back in about 1972, back when the original ECCS model came through. So we will probably want to look at that again if there is any core uncovery predicted.

Let's see. I have one more slide, if you can bear with me.

(Slide change)

MR. JENSEN: This is what RELAP predicts for the flow in the hotleg when the ADS-4 is operating.

MEMBER WALLIS: Thirty meters a second?

MR. JENSEN: Thirty -- Yes, please, I left off the -- The top curve should say steam flow, and the bottom curve should say liquid flow.

MEMBER WALLIS: Ah. You liquid flow is actually catching up with the steam.

MR. JENSEN: The liquid is the bottom one, and it's just kind of bouncing around zero. It's fairly low. So ADS-4 opens at about 2900 seconds, and then the IRWST comes on at around 3500 seconds, which is this big water slug coming out. But I guess what I'm trying to show here is the steam velocity. It's pretty high in this hotleg.

RELAP predicted the flow was annular. It didn't think the flow -- based on its flow regime map, didn't think it had stratified flow at all. It thought it had annular flow. So it's carrying all this then out the ADS. So this is --

MEMBER WALLIS: What's happening in the vessel? Is the vessel level higher than the hotleg here?

MR. JENSEN: The vessel two phase level is up even with the hotleg, I think. It's carrying out two phase.

MEMBER WALLIS: Even?

MR. JENSEN: It's up in there, up in that region. Whatever is coming up is carrying it out.

MEMBER WALLIS: I'm just saying the flow regime is going to depend very much on how the liquid gets in there at the end. It comes in as droplets. It's not going to be instant in the annular flow, for example.

MR. JENSEN: Right. So this is the kind of thing we can use RELAP for. Maybe we don't believe the flow regime, but we can say, well, we know what -- it's telling us what the steam velocity is, and we want to be sure that the data that we are using, when we find some to benchmark WCOBRA/TRAC, is applicable for velocities of this magnitude.

So we have a lot to do here.

MEMBER SCHROCK: These predictions were done with RELAP?

MR. JENSEN: Yes. This is RELAP. That's all I have to tell you about NOTRUMP. Entrainment is going to be a big problem.

CHAIRMAN KRESS: Okay. With that, we are at the point where we would like to hear what Westinghouse has to say about that.

MR. CORLETTI: I guess we can just summarize our plans going forward. We are doing our plant calculations with NOTRUMP. We also are preparing our topical report, which is our ADS --

using COBRA/TRAC, looking at the ADS-4 IRWST transition phase.

We are validating that against the test data at OSU that was already performed for AP600. We are going to show that and also show plant calculations with that as part of this topical report we will be submitting with our application.

The purpose there we hope to show is that with such a code that NOTRUMP is still performing a conservative representation of the transient. That is going to be part of our phase 3 review.

MR. CUMMINS: This is Ed Cummins. To summarize our position, it's very similar to the staff's. In LOFTRAN their comment was we were sensitive to two phase events, if they are predicted.

Our current analysis doesn't predict two phase events for the steam line break, but the staff hasn't reviewed that, and it's intended to be reviewed in phase 3.

In NOTRUMP, basically, we discussed entrainment yesterday, and I think we wouldn't quite agree with this is a big problem. We think in some respects it is self-limiting, because H is cubed as well as steam flow. But this is something that we don't intend to resolve in phase 2. We intend to resolve in phase 3.

We agree that, if NOTRUMP shows core uncovery, that that invokes this LOCTA code and that it was appropriate for the staff to review it.

Thirdly, we agree that the heat exchange model in NOTRUMP is applicable for less than 1.5 feet per second and, if it's greater, then it has to be adjusted downward to be conservative, and we intend to do that.

CHAIRMAN KRESS: Okay. At this point we are going to turn to WGOTHIC, but I wonder if the members would like a break first.

MEMBER WALLIS: I think, as we just have one more topic, we might take a break now and then --

CHAIRMAN KRESS: That's what I thought we might want to. So let's take a 15 minute break. Be back at ten o'clock.

(Whereupon, the foregoing matter went off the record at 9:47 a.m. and went back on the record at 10:03 a.m.)

CHAIRMAN KRESS: Okay, let's turn now to the Gothic novel part of this thing. The word Gothic invokes visions of Frankenstein. No comment about the speaker, of course. Okay.

MR. THROM: Good morning. My name is

Edward Throm, and I am currently in the Plant Systems Branch of NRR, and I'm in the new division called Design Review Section.

I'm going to be going over the WGOTHIC review for the AP100.

(Slide change)

MR. THROM: Since it always comes up, I did look it up again, and GOTHIC stands for Generation of Thermal-Hydraulic Information for Containment. So it's a word that has a meaning, and WGOTHIC is an extension of the numerical applications incorporating GOTHIC4.0 code.

The extension is the inclusion of the Kline model which is the Westinghouse model that addresses the passive containment cooling system, which is basically using condensation on the inside of the containment and evaporation of the water flow on the outside of the containment.

In the supplemental package I do have a caricature of the system. Water is basically poured onto a bucket on top of the containment. The bucket is not really on the containment. It's elevated from the containment, and then it is distributed through two sets of weirs such that there is uniform flow of the water down the shell of the containment.

Air through buoyancy driven forces comes down the downcomer, up a riser section and out through the chimney, and the water is evaporated and the heat carried off through the chimney channel.

(Slide change)

MEMBER WALLIS: And the water evaporates before it reaches the ground or the bottom?

MR. THROM: Yes. Part of the modeling that is done in WGOTHIC is to make sure that the amount of water that is being evaporated is only the amount of water that can be evaporated.

What would normally happen is there is a drain line at this elevation, and any excess water would flow down that drain.

MEMBER SCHROCK: Is the aspect ratio realistic in this picture?

MR. THROM: No. That is just a caricature. I cut it out of another document.

MEMBER SCHROCK; It's much taller.

MR. THROM: Yes. There are -- I couldn't find any real good pictures, but it was just a sense to remind you again of what the passive containment cooling features are.

WGOTHIC is described in Westinghouse topical report, WCAP-14407, and the staff's safety evaluation was presented in NUREG-1512. So those two documents are the code.

Basically, the code approved in Part 52. Approval of the methodology is done as part of the design certification. So the approval of WGOTHIC for the AP600 is part of that design certification.

It's also necessary to point out that in developing and approving WGOTHIC we came up with what we called an evaluation model, not necessarily at the level of detail you see in an Appendix K model but, nevertheless, we needed a term to identify what we were talking about.

So the evaluation model conserved the aspects of using lumped parameter networks for the representation of the containment, issues concerning circulation and stratification, and issues concerning the use of the PCS flow and the mass and heat transfer models that were developed to model and conserve the passive containment cooling system.

(Slide change)

MR. THROM: As we are all aware, the large scale test facility which Westinghouse used was not well scaled for the blowndown portion of a transient. So the problem we had was not having a good scaled facility to assure ourselves that we really understood circulation, stratification, and some of the other issues that would be of importance if we were trying to do a quality calculation against a good set of data.

So during the development of the model, we looked at the international code databases. Specifically, if you want to read the information, you can look at Section, WCAP-14407 or Section 21.65 of the WCAP -- of the NUREG 1512.

In order to feel comfortable or justify the use of the lumped parameter approach, we went out into the international database, looking at the Battelle Model Containment and the HDR.

The HDR -- there were a couple of experiments that were done there where they sprayed water on the outside of the containment shell. What you see from the application of the GOTHIC code or tools like GOTHIC to the international database is the lumped parameter tends to homogenize the steam with the noncondensables, basically the air in the containment, and as a result, what's being condensed near condensing surfaces usually has a lower steam concentration that you might expect, and you generally always overpredict pressure, and pressure is one of the key markers for containment analysis.

When you apply regulatory requirements to these calculations, you really come up with a very conservative calculation for pressure.

This basically -- We confirm Westinghouse's contention that the lumped parameter model is appropriate for use.

(Slide change)

MR. THROM: The other issues that you wound up with in not having a properly scaled facility were circulation and stratification. In order to address these concerns, Westinghouse presented, and we ultimately accepted, a very conservative approach.

One approach is that after blowdown, Westinghouse turns off the heat sinks below the operating deck. So if they calculate steam going back down below deck, they don't take credit for the condensation.

In order to address the issues with circulation and stratification, two things came up. One is the developing of a condensing surface on a floor. Westinghouse has elected not to take credit for that.

The other big concern was potentially getting an air blanket on the operating deck as part of the stratification issue perhaps in the long term.

So Westinghouse also takes no credit for condensation on the upper deck.

So that was the mechanism for addressing the uncertainties and saying we really know where the steam is, and we can take full credit for it. We've elected to be conservative in those particular aspects.

The heat and mass transfer correlations: There was a lot of separate effects tests done by Westinghouse. There is published data, and all of that information went into developing the correlations for mass and heat transfer used in the WGOTHIC code.

As we are all aware, there's a lot of scatter in data. You can draw a line. You can try to draw a 95 percent confidence line. What Westinghouse did was they put bounding multipliers on the mass and heat transfer correlations to basically bound the data when doing the calculation.

They also used the conservative mass and energy approaches that are prescribed in the standard review plan where, during either the LOCA or the steam line break, you maximize the energy release and the mass release to its ultimate almost. You look at a large double-ended break. You use Moody multipliers for the low -- You make sure all the stored heat is reduced quickly.

In the steam line break, similar conservative mass and energy methodologies are prescribed, and Westinghouse basically uses those in their evaluation model.

So overall, the model that has been developed and approved is a very conservative calculational tool.

(Slide change)

MR. THROM: You start looking at some of the differences between the AP600 and the AP1000, and it was pointed out yesterday, this is just simply a 76 percent power uprate evaluation. Nonetheless, these differences aren't as marked as they might be.

Even though the initial inventories for both LOCA and main steam line break, the inventory and the energy stored in the primary or secondary system is larger. The pipings haven't changed. The coldleg where the break is going to be for the LOCA is the same size in the AP600 as the AP1000.

So your concern there is now the rate as being slightly different, not significantly different. Similarly, in the steam line break they have the flow restricter in the line, which again, even though you have the larger inventories and energies to release, the rates are not appreciably larger than you would expect for the AP600.

MEMBER WALLIS: Well, it's a race, because the total amount of energy is bigger.

MR. THROM: Yes.

MEMBER WALLIS: So that, if the rate is rapid, you are putting in an impulse of significantly more energy into the containment.

MR. THROM: Right.

MEMBER WALLIS: Large LOCA, for instance.

MR. THROM: Yes. But you see that there is the compensating factors within the containment are basically the free volume is increased so that compliance helps out a lot. The containment shell itself is a little thicker, and they do put more water on than they did previously with the AP600.

CHAIRMAN KRESS: For the question of the mixing in the containment, the lumped parameter node, have you given any thought to using a CFD code to look at that?

MR. THROM: Not at the staff level, no. We think that, in general, if you look at scaling of the break jet, you are going to see that it kind of supports the well mixed assumption. All the evidence out there does support it.

Where you see some conservative in the evaluations, I think, for some of these real high energy jets, you would expect the steam to almost hit the ceiling or the dome of the containment where it's really cold due to this water, and get significant condensation.

Whereas, in the lumped parameter model, as I said earlier, you are going to be always mixing this with the air. So there's going to be a tendency to decrease the condensation rate and basically calculate a somewhat higher pressure.

CHAIRMAN KRESS: Well, I was worried about hydrogen stratification, which goes the other way, you know. You don't want to assume well mixed there. You want to know what you actually have.

MR. THROM: Right. And we don't believe we have that particular issue for the design base events.

CHAIRMAN KRESS: Because that's not enough hydrogen to deal with.

MR. THROM: That's dealt differently. There are other things that come into play when you look at hydrogen, when you look at equipment qualification, when you look at subcompartment loads.

GOTHIC is part of the tool, but there are other things that come into play when you look at those. So what we are really focusing on here right now is the Chapter 6 evaluation for the peak pressure response for the containment.

(Slide change)

MR. THROM: Westinghouse looked at these changes. First of all, there's nothing that changed in the PIRT. The rankings are basically the same. Actually, they are the same. The process has not changed. It's condensation on the inside of the shell, evaporation of water on the outside of the shell.

So we've not identified any new phenomena that need to be included in the models. However, we did feel quite concerned that the mass and heat transfer models still be used within applicable ranges, and the focus of the review was on that particular aspect, to go back and look at the mass and heat transfer correlations and look at the expected response of the AP600 to assure that the mass and heat transfer models and the tests that were run to develop those models covered the range of the AP600.

MEMBER WALLIS: These are natural convection models?

MR. THROM: Natural convection.

MEMBER WALLIS: High Rehle numbers beyond most of the database.

MR. AUSTIN: This is Rick Austin from Westinghouse. The Rehle numbers are very high for AP1000 and AP600.

CHAIRMAN KRESS: 10^{10}?

MEMBER WALLIS: Are they beyond the database, the Rehle numbers?

MR. AUSTIN: In the chimney they are. There's a table in WCAP-15613 that compares the heat and mass transfer correlation -- the dimensionalist groups for the heat and mass transfer correlations, with a test data range, the AP600 range and the AP1000 range.

MR. THROM: And what he is talking about is the chimney area, which is up here. And because there is insufficient data to cover those ranges, Westinghouse uses the Ichida correlation in that area, and that's deemed to be a conservative correlation.

So that's kind of the one aspect where within the data that's the place where it wasn't adequately covered by any experiment. So Westinghouse in the evaluation model -- they elected to use Ichida correlation for that particular regime.

Basically, what you see when you look at the dimensionalist numbers, the Grashof number, Reynolds number that you use in the correlations, for the most part, the AP1000 brings those numbers up into the higher range of the data, but they are covered.

That's covered in the WCAP that Westinghouse provided and verified by -- They have done scoping calculations and backed out the numbers and have shown that the peak numbers are within the range, and they are not really pushing the upper bounds of any of the ranges.

When they looked at the film flow, they found out that the lower end for the Reynolds number in the heat flux data that they have for film evaporation was still being covered.

The one concern that we did have was with the higher power, higher energy being reduced by a LOCA, we were somewhat concerned with the peak shell temperature before a credit would be taken for the PCS, and it was probably from a statement that was made in one of the topicals that said, well, if you got really hot, you know, there might be a problem, but we didn't find any design basis events that would do that.

We challenged Westinghouse on that, and they did an evaluation that showed that the peak shell temperature prior to credit for the PCS water would be about 180 degrees. So the film model that's being used in WGOTHIC is applicable.

We were concerned that, if the shell temperature had gotten up into the 212 degree range where we might have to worry about a boiling front or potential breakup of the film, that that would be a concern. But calculations they have done and some preliminary calculations we have done indicate that that is not going to be a problem for the AP1000. A lot of that is due to the thicker shell.

MEMBER WALLIS: This run down the shell is -- Does it run as rivulets?

MR. THROM: It's a film.

MEMBER WALLIS: It's definitely a film?

MR. THROM: Yes.

MEMBER WALLIS: It's so much water that it really wets everything?

MR. THROM: Yes. Yes. It doesn't necessarily cover the full circumference of the shell. They have -- The water distribution tests were run by Westinghouse. These were basically full scale, partial height tests where they were done cold, but for different flow rates they came up with the coverage that you would have on the shell, and that's part of the model.

You would expect, actually, somewhat larger coverage in a heated environment, but we don't take any credit for that, because we don't have any data to really do that. So we look at, for example, early on about 90 percent of the shell being covered.

Later on, as the water flow rates decrease, it drops off to like 50 percent, and then 25 percent, but there's adequate --

CHAIRMAN KRESS: But they are using the same numbers for the AP1000?

MR. THROM: We think they are. It's one of those phase 3 things where we get to it -- I'll cover some of the issues that are going into phase 3. They basically parallel phase 2.

The thing is at this particular point the analyses that Westinghouse first presented back in December were with a one-node model, which we hadn't seen before. It gave us a lot of difficulty.

They came back in with a revised calculation in September which went back and used the 109-node model that they used in the AP600. They couched those as unverified results. However, as scoping calculations, those were the numbers that --

the calculations that they used to go back into the experimental database to assure themselves that they weren't creeping up on any ends of the data where, when the final calculations are done, you would expect to have an issue with needing more information.

That particular comment leads into one of the early concerns we had with the larger height of the containment and the potential for more complex mixing patterns that could influence the mixing and the buoyancy.

We expected less homogeneity of the environment and potentially higher temperatures in the dome, and with the one-node model we didn't see how they could address that issue.

They have gone back now, and they are using the multi-node approach. So we believe that the calculation they get will address these changes and also still lead to the conservative pressure calculation.

The scope -- As I said earlier, the scoping studies performed by Westinghouse show that the mass and heat transfer correlations are being used within their acceptable ranges. We don't -- other than the issue with the Rehle number and the chimney. That's already addressed through the Ichida. But when you look at the mix convection or the assisted convection correlations that are being applied, the data is applicable to the scale of the AP1000.

Well, in summary, the phase 2 review, we've not identified any new phenomena that we think need to be incorporated in the models. The current rankings remain unchanged, and they have some heat transfer correlations that are being used within their applicable range.

Using the approved model and methodology, we believe that the WGOTHIC is applicable for the AP1000.

As I pointed out earlier, when we get into phase 3, we need to confirm most of these findings. The calculations we have seen today still have not applied the evaporated flow model, and this is an iterative process that Westinghouse uses to assure that they don't have numerical instabilities in the code.

That basically is a methodology for only applying as much water as you can basically evaporate, and that was approved as part of the original calculation, but using the evaporated flow model in combination with the Chun and Seban correlation, one of the restrictions we put on the evaluation model to address wavy flow.

The standard review plan mass and energy release is one thing that is not yet done in the scoping analysis. In the standard review plan, for a pressurized water reactor after blowdown, there is a 30, 90, two minute period of time called refill at which time the accumulators are basically condensing the steam that is in the reactor vessel, and there's no real release into containment, although in the real world you would expect that the heat structures would be condensing the blowdown steam, in the standard review plan the expectation is that you collapse that region.

So you don't get any credit for heat removal while there is no mass and energy going into containment. The calculations they have done haven't included that, but they should not be any significant impact on the application of the mass and heat transfer models. It's just that we haven't really got the committed to design basis action evaluation done in accordance with the standard review plan, which is the expectation.

Also the calculations we have seen to date for the AP1000 are still using basically the ADS-4, IRWST and sump injection and mass flow rates that were developed during the AP600. If you remember, it's the ADS-4 counteracted by the IRWST that leads to and turns around the second peak.

So, you know, those numbers need to be developed in the final analysis. While we don't expect that any of this will lead to exercising the mass and heat transfer correlations outside their range, we want to look at it again, particularly.

We have them in the safety evaluation, a requirement that when the mass fluxes on a containment shell get much larger than the AP600, Westinghouse has to revisit the Kline numerics to make sure that there aren't any instabilities in that. So that's part of the final review.

At this particular time -- In the background package there's two pages of all of the conservatisms that are in the evaluation model. There's a lot of them, almost point by point. The input is taken to be conservative.

MEMBER WALLIS: Your design pressures are psia in the way it's put here?

MR. THROM: Yes.

MEMBER WALLIS: So you've added 14.7 or something?

MR. THROM: Yes.

MEMBER WALLIS: Can't really use the correlate psig. Atmospheric pressure goes up and down a bit. There's a difference.

MR. THROM: Well, yes, but when you -- If you want to use a percented ranking, you really should use absolute. That's the only -- I guess in today's environment we should be using some type of Pascal anyway

MEMBER WALLIS: Do you have predictions -- they have predictions yet for the AP1000 max pressure in the containment?

MR. THROM: Yes, we have two sets of calculations from Westinghouse. We have the scoping calculations which were not done with the model we expected to see, but for the main steam line break they were calculating on the order of 70.7 psia.

MEMBER WALLIS: So it's pretty close.

MR. THROM: Close, yes. And in containment you will basically see that it is always very close, but understand that the calculation is extremely conservative.

For the LOCA, in the scoping calculations that were presented to us back in December of 2000, those again didn't really comport with the standard review plan methodology. What they used there was a five-hour time period to remove the sensible heat from the primary system, where in the SRP methodology you basically do that over an hour.

So that calculation showed that the peak pressure was about 60.7 psia, but that's not a fair marker. In the calculations they provided in September where they went back in and started going to the detailed model, they went back in and used the one-hour time period, and I believe they are calculating just about the same number now for the LOCA, about 70, in that ballpark.

So there is a chance that things might change a little bit, once all of the final boundary conditions are input into the code.

MR. BOEHNERT: What's the design limit?

MR. THROM: Excuse me?

MR. BOEHNERT: The design limit, Ed?

MR. THROM: 73.7. That's along about slide 3. There is margin. I mean, in the AP600 we cut even a lot closer than that.

(Slide change)

MR. THROM: We have developed a contain-2 model. I've got a picture of it up here for those who are interested. It's got 26 nodes in it. What's not shown is the environmental node that's node 26.

It's similar in nature to the WGOTHIC model, but we don't have as much detail in the model. The progression of Westinghouse's development of the AP600 model into more noding than they probably really needed, because they were looking at a different approach early on.

We have done calculations using the scoping data, which is not final data, and for the main steam line break we calculated 69.4 psia as compared to the 70.7 that Westinghouse got.

In the contain model that we developed it was an offshoot from the AP600 model, which was developed very early in the process. In the model we have modeled all of the heat structures. We've modeled the heat structure for the upper deck.

So when we did the scoping evaluation, we calculated 54 psia as a comparison to the 60.7 that Westinghouse got for the same type of calculation. What we did do -- and the problem with contain is it meets everybody's expectation that there are no dials in the code that make the analyst's job easy to turn things on and off.

What we were able to do was mimic the mass and heat transfer penalties. When you apply that to the calculation, you see a 2 to 3 psi increase. So the calculations are fairly comparable. The main steam line break is showing to be the one, I think, from the pressure point. We are getting about the same calculation in most of the PCS characteristics.

The heat structure characteristics are really not impacted by the main steam line break, basically because of where you release the steam in the model. You release it at an elevated location. The lumped parameter model has a difficult time of getting the steam back down into the areas where you have the concern about how you address potential stratification and mixing.

So we expect that WGOTHIC is applicable to the AP1000, basically, within the context of the evaluation model and the conservativeness of the input and the look at the international database and the use of the lumped parameter model.

What we've seen to date suggests that, when the design calculations are done, the mass and heat transfer correlations are going to be used within their applicable ranges, and there is no need to broaden the database.

That's all I have.

CHAIRMAN KRESS: Are there any comments or questions from the members before we hear from

Westinghouse response on this. Seeing none, I guess we will see if you have any comments you would like to make.

MR. CUMMINS: This is Ed Cummins. We are in basic agreement with the staff's conclusion. We would like to respond to an earlier ACRS question relative to CFD modeling, and show you what we have calculated. Rick Austin is going to do that.

CHAIRMAN KRESS: Great.

MR. CUMMINS: Thank you.

MR. AUSTIN: Okay. My name is Rick Austin from Westinghouse Electric. I was asked to present some work that we did to qualitatively compare the mixing in AP600 to AP1000. We did this when we were looking at the PIRT and the scaling issues, and it's contained in the WCAP-15163.

(Slide change)

MR. AUSTIN: We looked at -- WE built models of the AP600 and AP1000 above deck operating region in two dimensional CFD code. Star 3-D it's called. Those results, as I said, are presented in 15613. We showed those results to the NRC in, I think, the Thermal-Hydraulics -- ACRS Thermal-Hydraulics Subcommittee.

Dr. Wallis asked us if we could look at

that in 3-D. So Dr. Milorad Dzodzo -- he's our CFD code expert -- put together a 3-D pie slide model with the same CFD code.

MEMBER WALLIS: A 1.5 degree pie?

MR. AUSTIN: 1.5 degree --

MEMBER WALLIS: Pretty thin sliver of pie.

MR. AUSTIN: -- pie slice. The 1.5 degree pie slide model we built has approximately a million cells. So the computing time was excessive, and I think it took him a week to generate the results that I'm going to show here. I think he might have had a dual processor type computer, too.

MEMBER WALLIS: Now you said you had -- Well, you don't have a steam plume in there?

MR. AUSTIN: Yes. This is air only. We couldn't model the condensation of the steam.

MEMBER WALLIS: This is air only?

MR. AUSTIN: Right.

MEMBER WALLIS: But there is a heated --

MR. AUSTIN: There's a heated plate at the bottom. It simulates a hot wall at the bottom on here, and there's a cold wall here and a cold wall on top.

MEMBER WALLIS: In reality, you are injecting steam rather than having all plate.

MR. AUSTIN: That's correct.

MEMBER WALLIS; Why didn't you inject -- Oh, but you couldn't remove mass, I guess. In the CFD model, you didn't know how to remove the mass.

MR. AUSTIN: That's right. Couldn't condense the steam.

I guess when Dr. Dzodzo looked at that, he suggested that the steam, because it was lighter than the air, would have probably provided even a little better mixing --

MEMBER WALLIS: Because of more buoyancy, it tends to go up more.

MR. AUSTIN: Right. A little better mixing than what we would see with the CFD analysis.

So this first slide just shows the basic model that we put together. I don't know if this is going to come out very well. That's --

MEMBER WALLIS: I think it's just the noding. The whole thing is full of nodes.

MR. AUSTIN: That's the noding structure in the corners of the pie slide. It's highly detailed on the edges. I think he was trying to resolve the boundary layer. Those are like one millimeter size width cells there.

(Slide change)

MR. AUSTIN: This is a 2-D model prediction for the temperature distribution for AP1000, and I'll put up -- I probably could use two projectors.

(Slide change)

MR. AUSTIN: This is the 3-D model that results. I guess you can imagine both sides of that.

MEMBER WALLIS: You're going to have to tell us something. Everything looks a kind of uniform blue here. So I'm not quite sure. The other one showed more --

MR. AUSTIN: The colors are --

MEMBER WALLIS: The other one showed more clearly a circulation pattern. The other one shows a transition on the wall in color, which I don't see in the 1000. It may be just the way that the --

MR. AUSTIN: Yes, it's very thin -- a very thin boundary layer on this one. This one, you can see. It just may be the way the colors came out here.

MEMBER WALLIS: Well, the plume is more evident in that one, and the wall boundary is more evident in the righthand one.

MR. AUSTIN: Right.

MEMBER WALLIS: So does this say it's well mixed or does it show that it is a sort of circulating pattern with a not very well mixed region in between?

MR. AUSTIN: It shows a circulating pattern with a hot plume rising up the center and the colder plumes falling down along the outer walls. In the center portion -- There is a velocity profile plot here. The center portion or that little donut region -- this is what the 2-D predicted, and here's the 3-D prediction, same type of behavior.

The donut region around the middle there is -- That is somewhat stagnant. It doesn't have much velocity.

MEMBER WALLIS: So it indicates that you don't have a well mixed -- So then you are going to argue the well mixed is conservative, I guess. That's the Westinghouse position, isn't it?

MR. AUSTIN: Yes.

MEMBER WALLIS: This is not well mixed, but the well mixed assumption in the code is conservative?

MR. AUSTIN: Yes.

CHAIRMAN KRESS: I would have called this well mixed.

MEMBER WALLIS: Well, that blue region isn't particularly well mixed.

MR. AUSTIN: The blue region doesn't

circulate as much. There's very little circulation in that region.

MEMBER WALLIS: You have this sort of mixing in your breadmaker, you would get lousy bread. I don't know how to describe it to you.

CHAIRMAN KRESS: Does the CFD model have a turbulent term in it?

MR. AUSTIN: Dr. Dzodzo would be the expert on that. I'm not a --

MR. BROWN: Bill Brown from Westinghouse. I think it does, but I think you have to look at the range of numbers here, too, before you get carried away with making -- I think --

CHAIRMAN KRESS: That's what I was looking at.

MR. BROWN: Yes. The differences are very small, Dr. Wallis. They are very small.

MR. AUSTIN: The temperatures are real small.

MR. SIEBER: Ten degrees or so.

MR. BROWN: You are only talking a few degrees. So over the type of height -- we're talking about, you know, hundred feet plus.

MEMBER WALLIS: I think we have to look at the change in temperature of that blue annular region, whatever you call, Taurus sort of region. Did that actually warm up during the transient or not much?

MR. AUSTIN: Yes, this one shows -- Well, the temperature there is probably on the order of 370 degrees.

MEMBER WALLIS: So even the coldest bit warmed up a lot. Is that what we conclude? I can't really tell. What was the initial temperature compared with the temperatures we are seeing here?

MR. AUSTIN: The initial temperature -- The cold all is at 366k, and the hot wall is at 394k.

MEMBER WALLIS: And the initial temperature of everything was?

MR. AUSTIN: 385k. It's the average. We use an average temperature.

MEMBER WALLIS: When you use k, it's difficult to see the differences. I guess what I would want to know is how much did that cold region, the one affected region, change its temperature. You can't tell just looking at it. That dark blue blob, that elongated donut thing -- it doesn't mix very much.

CHAIRMAN KRESS: I think this is safe

calculation.

MEMBER WALLIS: Does it go up in the middle and down the wall in that thing?

CHAIRMAN KRESS: This is steady state calculation?

MR. BROWN; Yes. Bill Brown. This is steady state. This is after many, many iterations. That's why it took a week to get here.

MEMBER WALLIS: So now you have to do the transient.

CHAIRMAN KRESS: What this indicates to me is that with those kind of temperature differences inside the containment that you are very likely to have a well mixed containment.

MEMBER WALLIS: I think what we have to look at is the velocities here and see how rapidly a chunk of fluid goes around compared with how rapidly things are changing with time.

CHAIRMAN KRESS: Yes, that would be something --

MEMBER WALLIS: How close are we to Fauske's steady state? This is useful.

MR. BROWN: Bill Brown again. Don't forget that one of the original intentions you had here was just some interest in the 2-D versus 3-D result. So that was originally.

MEMBER WALLIS: Also 600 versus 1000, too.

MR. BROWN: Yes. That was originally why we did it, was to address the L/D type of aspect ratio difference. One thing we also notice that Rick may not have mentioned is that in the 3-D -- I believe, Dr. Kress, maybe you said this at one of the last meetings, that you expected maybe a little improvement perhaps in the results.

What we noticed is that, if you look on the picture on the left, that the plume actually wasn't quite -- from what we could tell in the details and looking at all the iterations, wasn't quite actually hitting the top of the containment, but now in the 3-D it actually is hitting the top of the containment. So we actually get a little improvement.

MEMBER WALLIS: First I will also tell you, heat transfer coefficients on the wall. Now this isn't condensation, but there's probably a way to go from the heat transfer coefficients you get here to what they should be with condensation in some way that you can sort of verify that heat transfer behavior is conservative or whatever you want to show. You should be able to get some heat transfer information on the wall from this sort --

MR. BROWN: We can get dry heat transfer, right.

MEMBER WALLIS: Yes, but then there's probably a way you can show, you know, by analogy or something. You can scale it.

CHAIRMAN KRESS: I'm pretty sure the CFD code has it modeled in it for the heat transfer. With that many nodes that small, it probably uses the conduction equation.

MEMBER WALLIS: Then you can compare it with some-- Well, you presumably used some kind of Rehle number correlation or something for the heat transfer coefficient?

MR. AUSTIN: Inside containment, yes. We used free conduction correlations.

MEMBER WALLIS: It would be interesting. This isn't just free convection on the wall. It's a driven circulation pattern. So it's somewhat different from just free convection on the wall. It would be useful for you to compare the two. You could probably show that neglecting the circulation is quite conservative.

Just use free convection on the wall. You may get a heat transfer coefficient, say, half as much as you predict here for the air case. That might help you. I don't want to do your work for you.

It would be useful if you could show, because of circulation, there is really more heat transfer, say, in air than you would predict using the kind of assumptions you use for your heat transfer calculation.

MR. AUSTIN: And we agree.

MEMBER WALLIS: And then that would be reassuring.

MR. AUSTIN: That's all I had.

CHAIRMAN KRESS: We appreciate that. That was very useful, I think.

MR. BOEHNERT: A question for Westinghouse. Those slides are labeled proprietary. Do you really mean that?

MR. AUSTIN: No.

MR. BOEHNERT: We can cross that off.

MR. BROWN: That was from my proprietary presentation. Those slides there aren't proprietary. Sorry about that.

CHAIRMAN KRESS: In the full Committee meeting in March we only have two hours to cover all the stuff we covered in a day and a half -- well, I guess one day, counting both of them. So we need to have some idea of how to condense all this.

My feeling is on yesterday's presentations on the DAC and the exemptions, I think you can just use one slide to tell what the exemptions were. I think everybody is in full agreement on those almost.

For the DAC, I think the comment that Westinghouse is going to request for the seismic structure a hard rock side makes things a lot easier in terms of what we say, because that sort of takes those out of DAC space.

So given that, I think you just clarify what Westinghouse intentions are there, and then that means we focus the issues of DAC on the piping. I think that may be one you want to really focus on, because I think that's one the Committee would have to make some sort of judgment on, if we want to give our take on it, our thing sort of.

I would focus most of the talk on the piping DAC. Now you have to do something about the codes, how to get all this -- I like the thought of the staff showing -- giving us an impression of what the depth of their review was.

You had a couple of slides that -- for talking about the code applicability and the data applicability. So if you could just give the full Committee an impression of the depth of your review and the basis for your conclusions on that.

With Westinghouse, I particularly liked that stuff you did to show from the entrainment that it's self-limiting, and I think that would be useful.

A lot of this on the code and the data, I think, is going to come down to the entrainment issue. So I would focus on that as much as I could during the two hours we have. This is the thing that I think is going to give us problems.

I think with the containment and GOTHIC, just a very quick overview on that. I didn't see very much contentious. Everybody seems to be in agreement on that. So I wouldn't do a lot with that. I would just point out what it is.

So if the members have some other thoughts on what the two hours might consist of, I would welcome comments at this point.

MEMBER WALLIS: Well, I'd like to see the scaling of the summary applied to the scaling that showed some of the inserts for red indicating the few areas where scaling needed to be investigated further.

CHAIRMAN KRESS: Oh, yes, definitely I'd like to see that, too.

MEMBER WALLIS: I think we need the picture showing entrainment in the two locations. I think we need sort of the summary picture of is there or is there not a possible issue with entrainment. I mean, the numbers, actually Jg*, and there's just one slide. I think there was a clear message there.

MEMBER SIEBER: I think you probably don't want to go through all the math and logic in the scaling.

MEMBER WALLIS: No. I don't think we need all Marino's equations.

CHAIRMAN KRESS: Although that was good stuff.

MEMBER WALLIS: I think there's a bottom line for Marino, is that if you make different assumptions about the void fraction, you get different rates of loss of inventory. That's sort of the bottom line. Maybe that can be done in five minutes.

CHAIRMAN KRESS: Yes.

MEMBER WALLIS: That sort of ties in with what Steve is saying. I think also in the RELAP you don't need anything like as much as we had this morning. What's sort of the bottom line with RELAP? What are you doing with it? Where is it going, maybe a couple of slides there.

MEMBER POWERS: Tom, may I make a suggestion, that for the staff presentation you invert the order and begin with Mr. Throm's presentation so that he can remind the members who are not here about AP600, because most of those members that are not here were not part of the AP600 review.

CHAIRMAN KRESS: That would be a good suggestion.

MEMBER POWERS: And he has a caricature that I think would allow him to point out some of the -- He used it to point out some of the key containment features, and I would encourage him to go ahead and do that.

He might just also note a few of the critical features for the discussion of the in-vessel phenomena.

CHAIRMAN KRESS: There was a -- in the chart with the table on it, comparing notes. That would be a good thing to have up there.

MEMBER POWERS: I would use a picture.

CHAIRMAN KRESS: Well, a picture is going to look just like AP600.

MEMBER WALLIS: A realistic picture, not with a lot of content.

MEMBER POWERS: Well, I mean, sort of the plant.

CHAIRMAN KRESS: But that chart showing

the --

MEMBER POWERS: What I'm thinking of is those members that are not here -- I mean, nearly all of them are --

CHAIRMAN KRESS: It would be a good idea to have a picture.

MEMBER POWERS: -- relatively new.

CHAIRMAN KRESS: Yes, and then the chart showing the differences between AP600 and AP1000.

MEMBER WALLIS: When words like CMT are used, there needs to be, you know, a very quick tutorial.

CHAIRMAN KRESS: Re-explain what those devices -- where they come into play and when they are used. That would be easy.

MR. CORLETTI: Would you like Westinghouse to do just a comparison, a five minute comparison of those two plans?

CHAIRMAN KRESS: Yes, I think that would be a good idea. Let Westinghouse do that.

MEMBER POWERS: The members that are not here, almost none --

CHAIRMAN KRESS: Yes, they are all new and weren't here for AP600.

MEMBER POWERS: -- were present for the

AP600, and nearly all of them are thermal-hydraulically averse. I like these guys a lot, by the way.

CHAIRMAN KRESS: Yes. What would be good would be a little short tutorial on the philosophy of the passive systems, where they come into play, and why, and that would be useful for those members, I think. A good comment, Dana.

Any other thoughts?

MEMBER WALLIS: Now we are supposed to write a letter on this?

CHAIRMAN KRESS: We have in mind a letter, because I think the staff plans to go to the Commission at the end of March with their feelings on both the DAC and the exemptions and the code applicability.

So I guess the Commission would appreciate our thoughts on those.

MEMBER WALLIS: So we would be both sort of endorsing some of the preliminary conclusions or something or saying that they are on the right track? There's no real conclusion yet, is there? So we got to be careful about it.

CHAIRMAN KRESS: Well, we'll be careful.

MEMBER WALLIS: Saying they are on the

right track.

MR. CUMMINS: Maybe I could make a comment, add comments. What we asked the staff to conclude was that the AP600 tests were valid for the AP1000, that the AP600 codes were applicable to the AP1000, and their position on DACs and exemptions.

So we didn't ask them to conclude the safety of the AP1000 plant, but we did -- There are some conclusions for which we would like to achieve.

MR. WILSON: This is Jerry Wilson. So what we are going to do is send a letter eventually to Westinghouse answering those questions that Mr. Cummins just summarized, but prior to sending the letter, decided we wanted to run it by the Commission.

So as you say, I'm sure the Commission will want to hear your views on it as they consider that.

CHAIRMAN KRESS: We'll comment on those four issues, I think.

MR. DZODZO: And if I may add a couple of comments, first I'd like to thank you for very insightful questions, and if there were any shortcomings in answering those questions, it was because a project limited to the otherwise unbounded curiosity of reviewers into a scope of phase 3.

My second comment is also that the reviewers also limited to design basis here. The applicability of some codes may resurface when I go into severe accidents, and in particular into source the calculations, since thermal-hydraulic conservatism sometimes is counterproductive to source the calculations.

As we know, the position mechanism are sensitive to local thermal-dynamic conditions.

CHAIRMAN KRESS: And we will look forward to reviewing those during the phase 3 part of the thing.

MEMBER POWERS: It strikes me, Tom, that we are going -- One of the central issues arises in connection with the DAC is the rule in Part 52 concerning the completeness of the design information.

CHAIRMAN KRESS: I think you're exactly right. That is the issue.

MEMBER POWERS: And the Commission that endorsed that rule is different than the Commission we have now, and we are going to have to discuss for them a little bit on why anyone would put such a silly rule in.

CHAIRMAN KRESS: I think you are exactly

right. In fact, in mentally thinking what might be in our letter, that was one of the things I had in mind discussing. I think you're exactly right. That's the central issue.

MEMBER SIEBER: Yes, it is.

CHAIRMAN KRESS: And particularly those two criteria, you know. So that, I think, will definitely end up in our letter, some discussion on that, and how it impacts on the question of the DAC for the piping. I think you're exactly right.

That's one reason I wanted a bit of concentration on the piping DAC issue.

MEMBER POWERS: It's a good object lesson. The other object lesson, of course, is the instrumentation and control, because that's a case where nearly everybody says, yeah, that's a good idea.

CHAIRMAN KRESS: Everybody agrees on that. Yes.

MEMBER POWERS: Yes, and so you got two to compare, and you need to compare up sides and down sides.

CHAIRMAN KRESS: Yes. I think that should be part of our discussions on the full Committee.

MEMBER POWERS: So this is going to be a difficult letter, isn't it? I mean, it's a lengthy letter.

CHAIRMAN KRESS: I don't think so. I've already got it written in my head. But maybe it will be.

MEMBER POWERS: The challenge that we face is translating from Tennessee to English.

CHAIRMAN KRESS: Oh, that will be difficult.

MEMBER SIEBER: I can't be any harder than New York.

MEMBER WALLIS: Well, I'm glad to hear that you folks understand what's going on with the DAC. I mean, you said there was a problem with new members understanding.

CHAIRMAN KRESS: Oh, that's right. You weren't part of the DAC.

MEMBER WALLIS: I haven't a clue what this DAC business is about. So you guys better understand it well.

CHAIRMAN KRESS: Yes, we think we know what DAC and ITAACs are, and Tier 1s and Tier 2s.

MEMBER POWERS: But we have to translate from English from Tennessee to English and then to academe use.

CHAIRMAN KRESS: Yes. You're right, it's

going to be difficult.

Okay. With this comment, have we given you enough guidance? Are there any closing comments anybody wishes to make?

Seeing none, I am going to declare this Joint Subcommittee adjourned.

(Whereupon, the foregoing matter went off the record at 10:58 a.m.)

CERTIFICATE

This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission in the matter of:

Name of Proceeding: ACRS Thermal Hydraulic Phenomena and Future Plant Designs Meeting

Docket Number: (Not Applicable)

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.

Pippa Antonio

Pippa Antonio
Official Reporter
Neal R. Gross & Co., Inc.

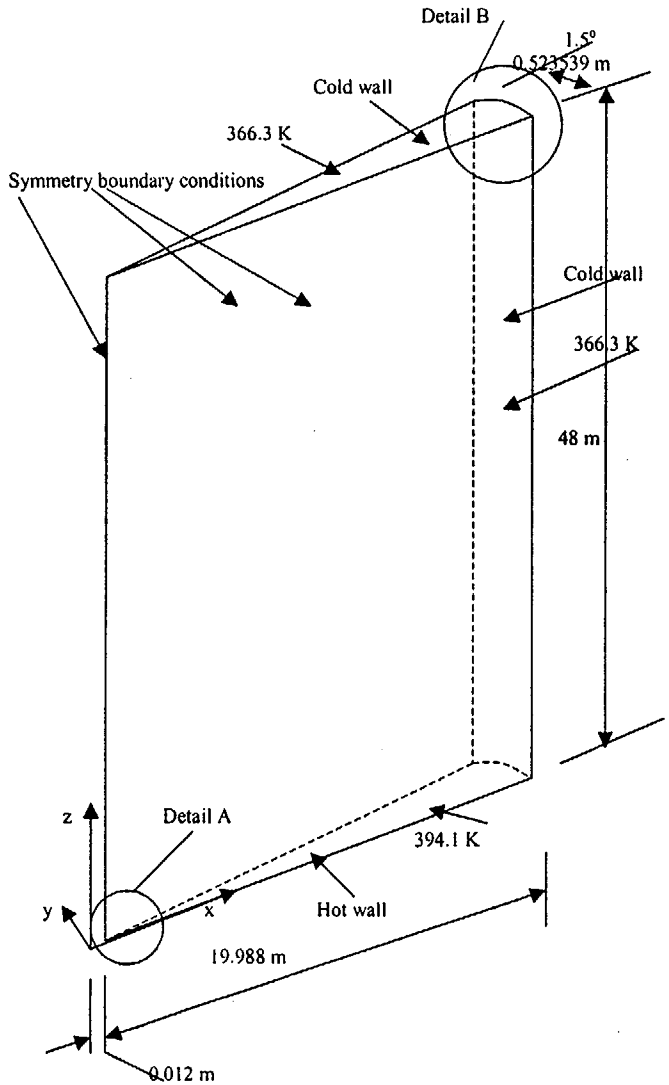
3-D CFD Air Mixing Evaluation

- Westinghouse presented a 2-D mixing evaluation comparing the AP600 to AP1000 in WCAP-15613 to determine the impact of increased height
  - 2-D vertical slice representing the volume above the operating deck
  - Both coarse and fine grid modeling used
  - Heated floor, cold ceiling and walls, air only
  - Models predicted a rising warm air plume in center, falling cold air plumes along the walls, and fairly stagnant air in between.

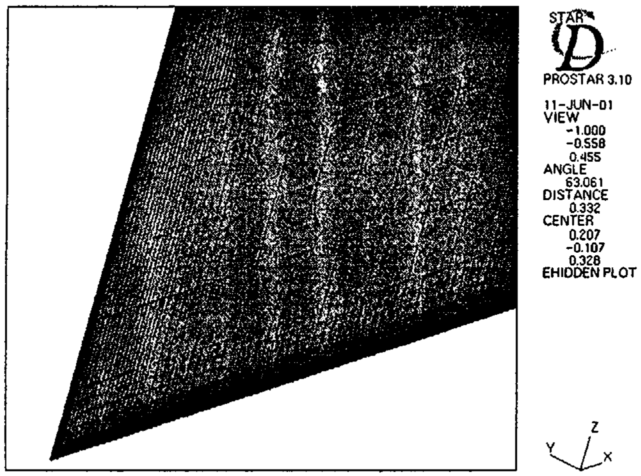
3-D CFD Air Mixing Evaluation

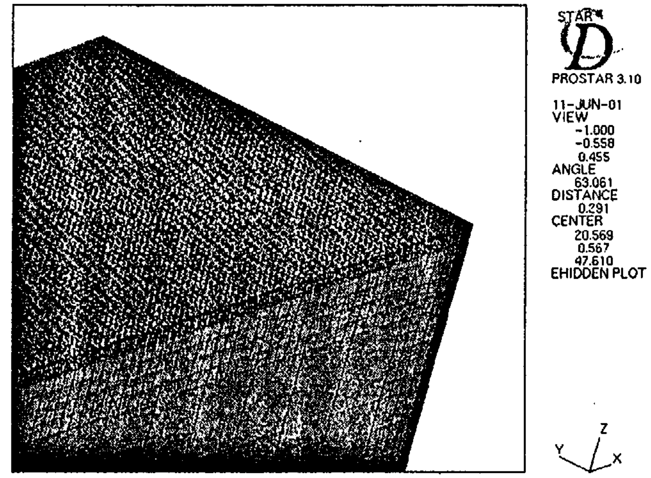
- Dr. Wallis asked us to perform a 3-D mixing evaluation for AP1000
  - Built a 3-D pie slice (1.5°) representing the volume from the center of containment out to the shell
  - Heated floor, cold ceiling and wall, air only
  - Model predicted a rising warm air plume in center, falling cold air plumes along the walls, and fairly stagnant air in between.
  - Warm plume reaches the ceiling in the 3-D model

3-D CFD Air Mixing Evaluation



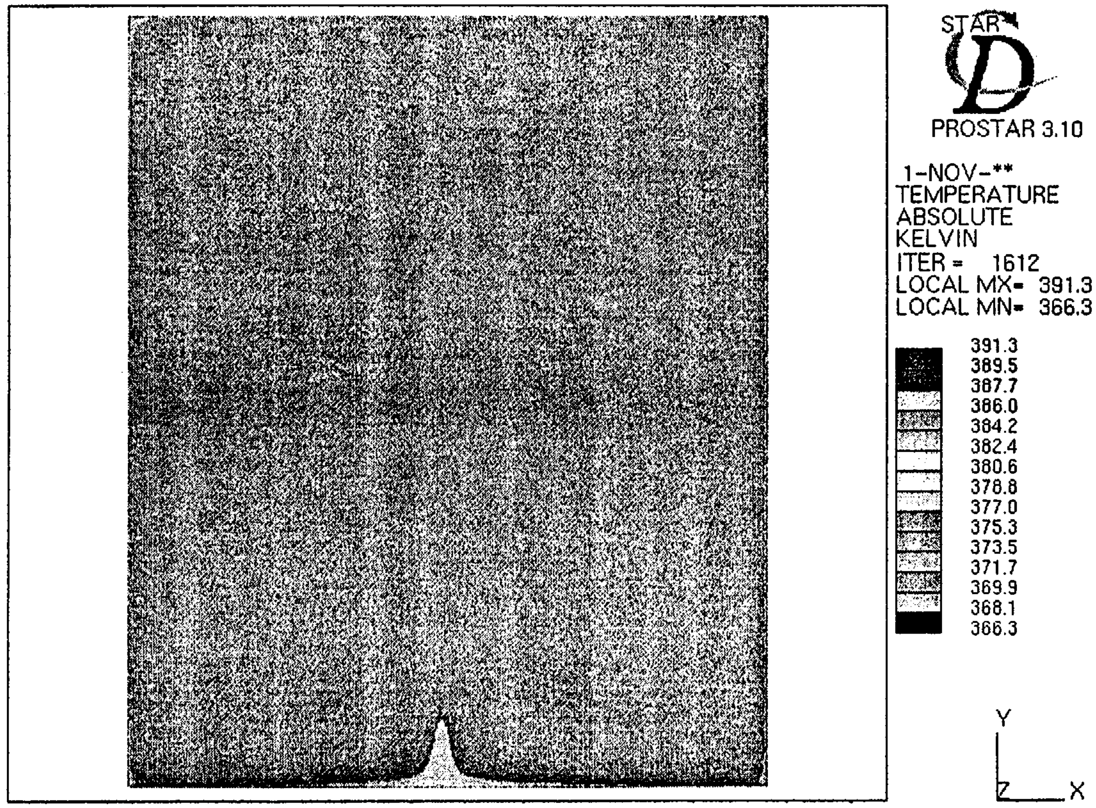
3-D CFD Air Mixing Evaluation





Detailed Noding Structure at Center and Outer Edge

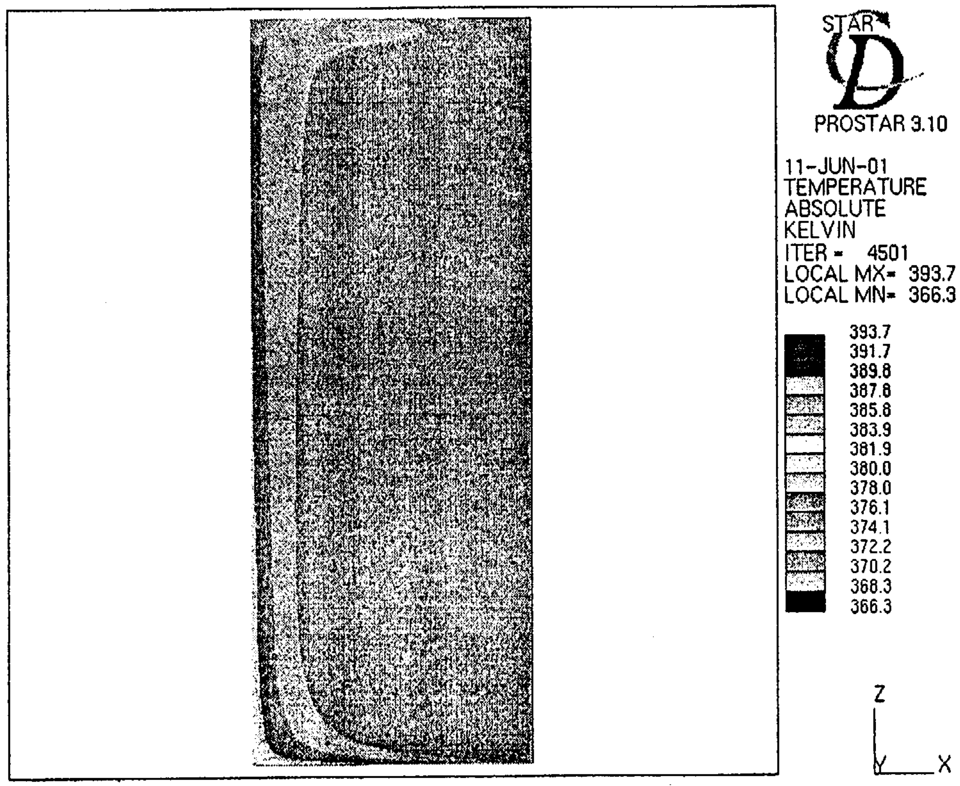
3-D CFD Air Mixing Evaluation



Temperature distribution (case AP1000_1 after 1612 iterations)

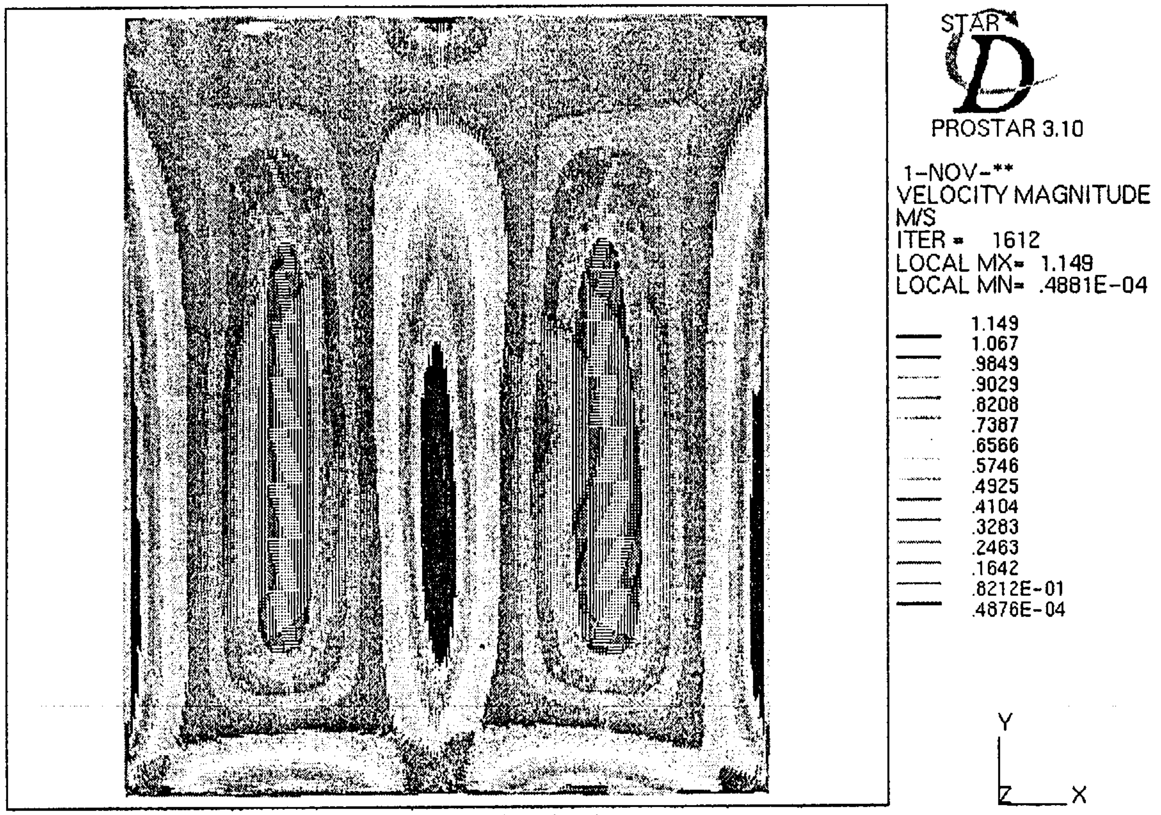
2-D Model Predicted Temperature Distribution

3-D CFD Air Mixing Evaluation



3-D Model Predicted Temperature Distribution

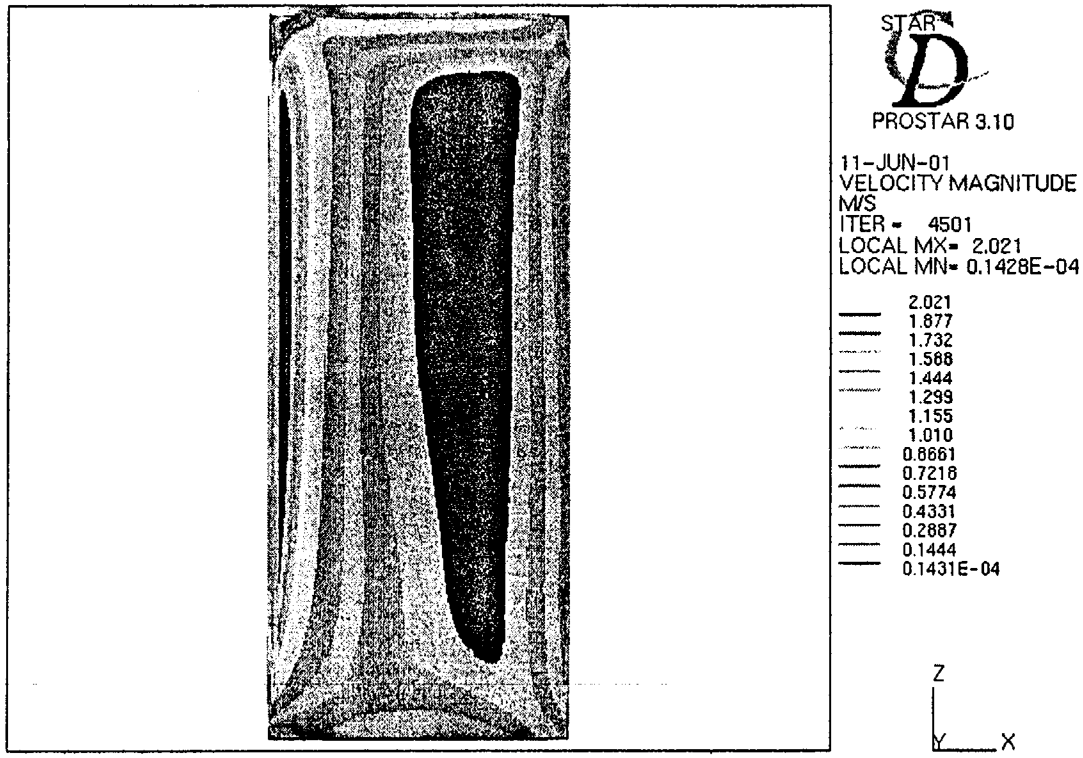
3-D CFD Air Mixing Evaluation



Velocity distribution (case AP1000_1 after 1612 iterations)

2-D Model Predicted Velocity Distribution

3-D CFD Air Mixing Evaluation



3-D Model Predicted Velocity Distribution

<u>Supplementary Figures</u>

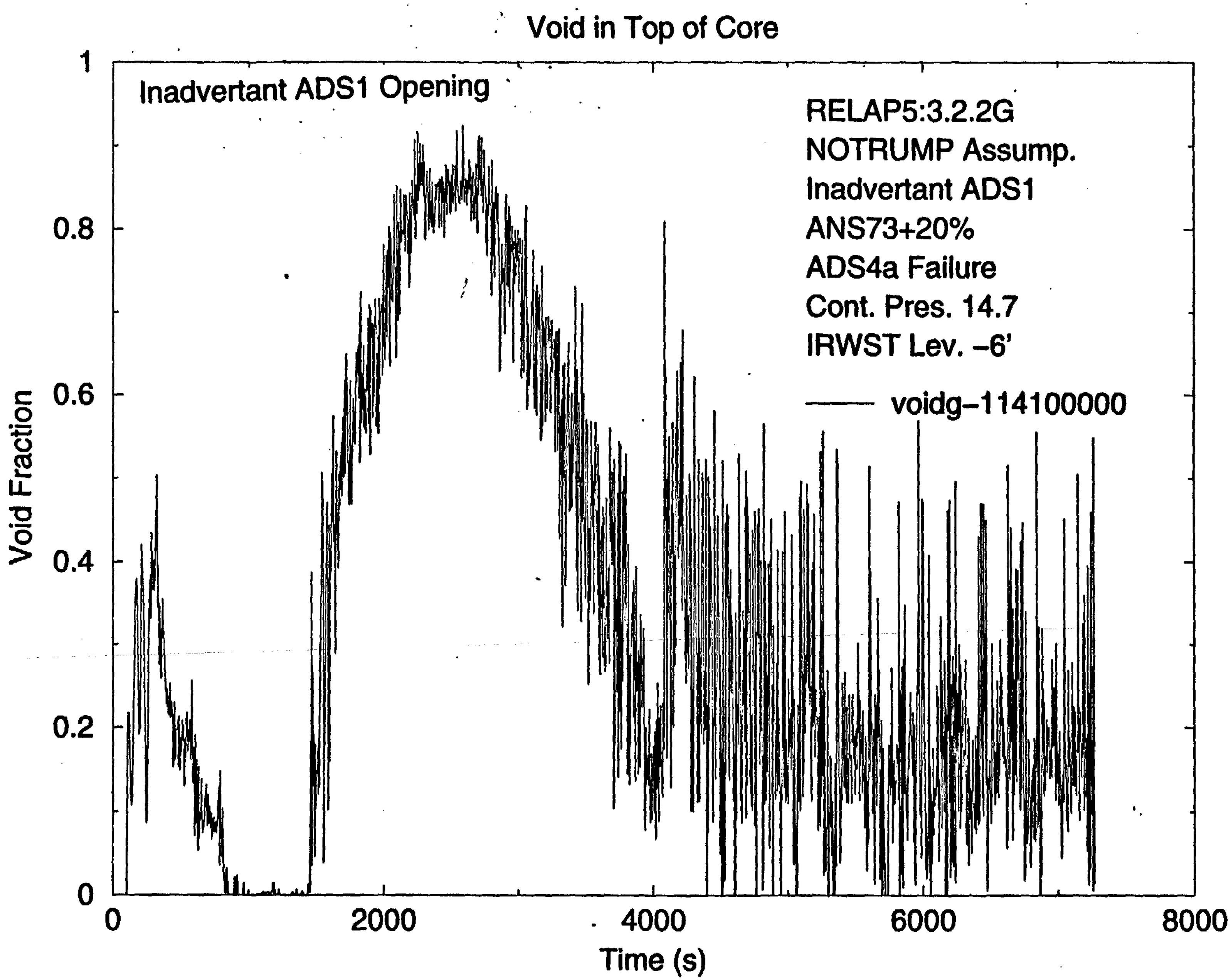
NRC Staff Review of NOTRUMP and LOFTRAN for AP1000

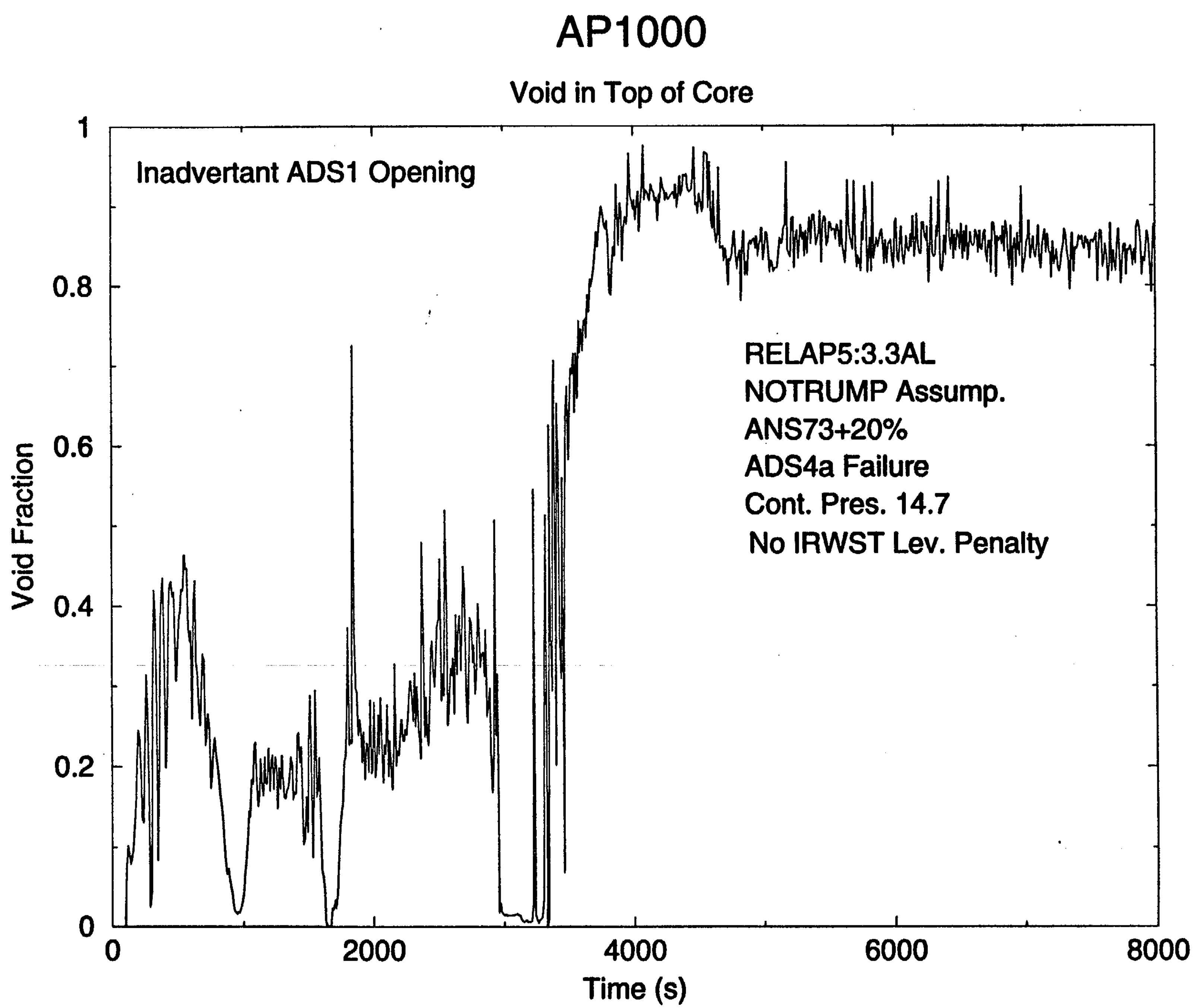
ACRS Thermal/Hydraulic Subcommittee Meeting
February 15, 2002

UNITED STATES NUCLEAR REGULATORY COMMISSION

Walton L. Jensen
NRC Staff

AP600

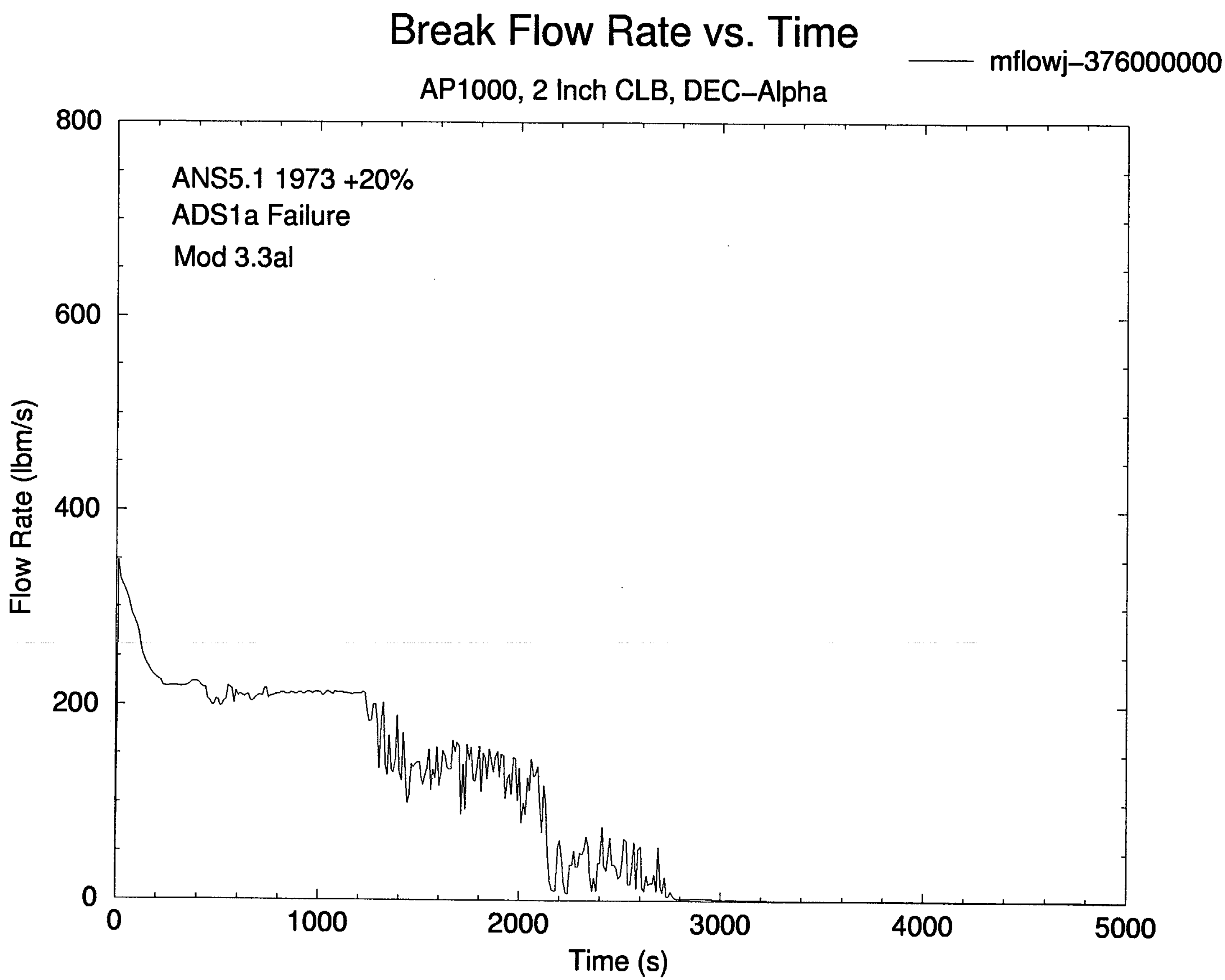

Void in Top of Core
Inadvertant ADS1 Opening
RELAP5:3.2.2G
NOTRUMP Assump.
Inadvertant ADS1
ANS73+20%
ADS4a Failure
Cont. Pres. 14.7
IRWST Lev. –6'
voidg–114100000
Void Fraction
1
0.8
0.6
0.4
0.2
0
0
2000
4000
6000
8000
Time (s)


AP1000
Void in Top of Core
Inadvertant ADS1 Opening
RELAP5:3.3AL
NOTRUMP Assump.
ANS73+20%
ADS4a Failure
Cont. Pres. 14.7
No IRWST Lev. Penalty
Void Fraction
Time (s)
0
0.2
0.4
0.6
0.8
1
2000
4000
6000
8000

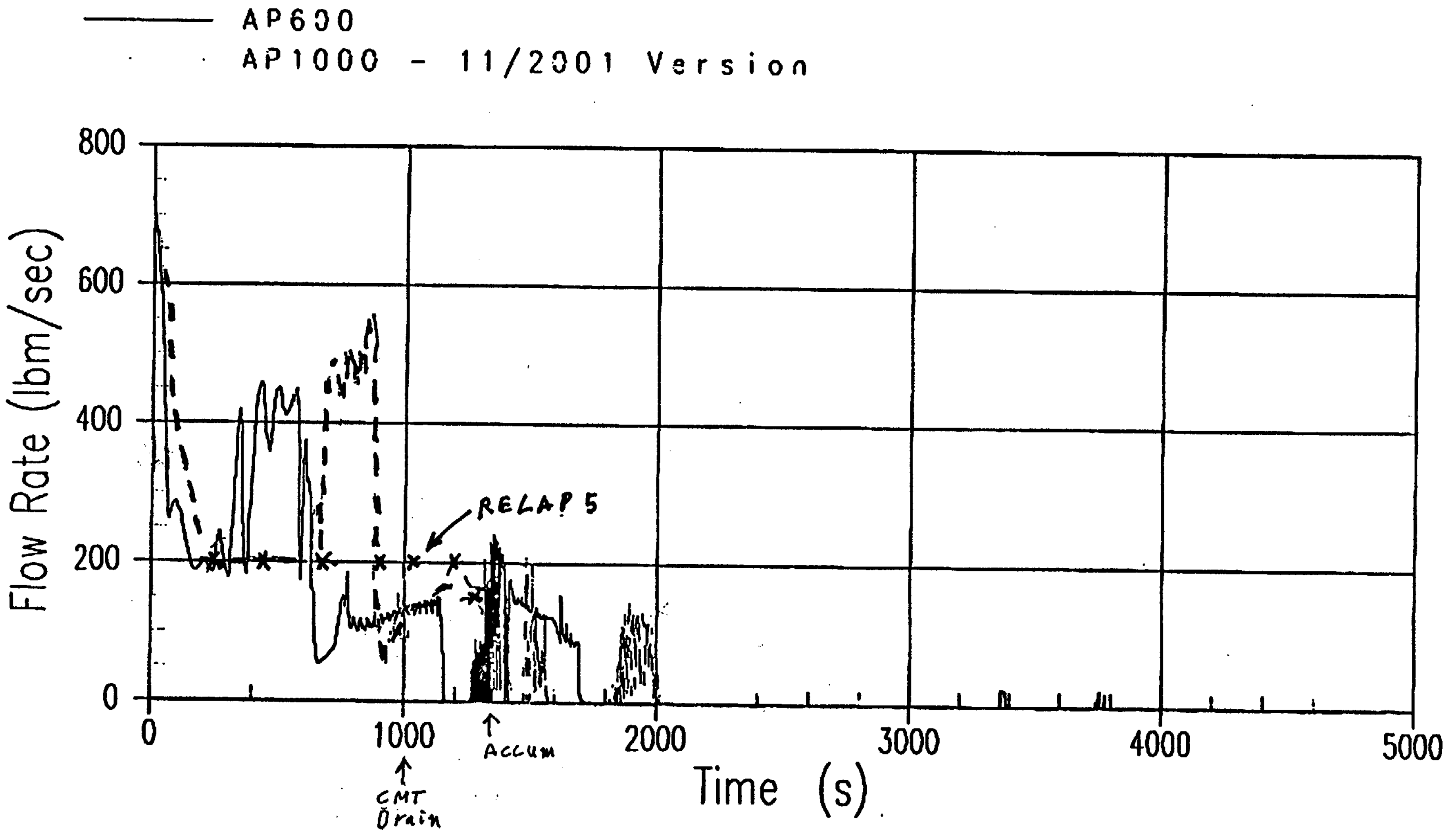
RELAP5 - NOTRUMP Comparison

Two-Inch Cold Leg Break

Event	Time (seconds)	
	RELAP5	NOTRUMP Nov. 2001
Break Initiates	0.0	0.0
Reactor Trip Signal	9.4 OPΔT	55.5
"S" Signal	52.4	62
Reactor Coolant Pump Trip	67.5	67.2
CMTs begin to Drain	1280	1000
Accumulator Injection Begins	1642	1447
ADS-1 Actuates	2097	1337.1
ADS-2 Actuates	2177	1467.1
ADS-3 Actuates	2297	1587.1
ADS-4 Actuates	2906	2490.1
Accumulators Empty	3020	1983
Voids above core > 90%	3156	
CMTs Empty	3580	2890
IRWST Injection Begins	3621	3300
Max. voids above core ~95%	3660	

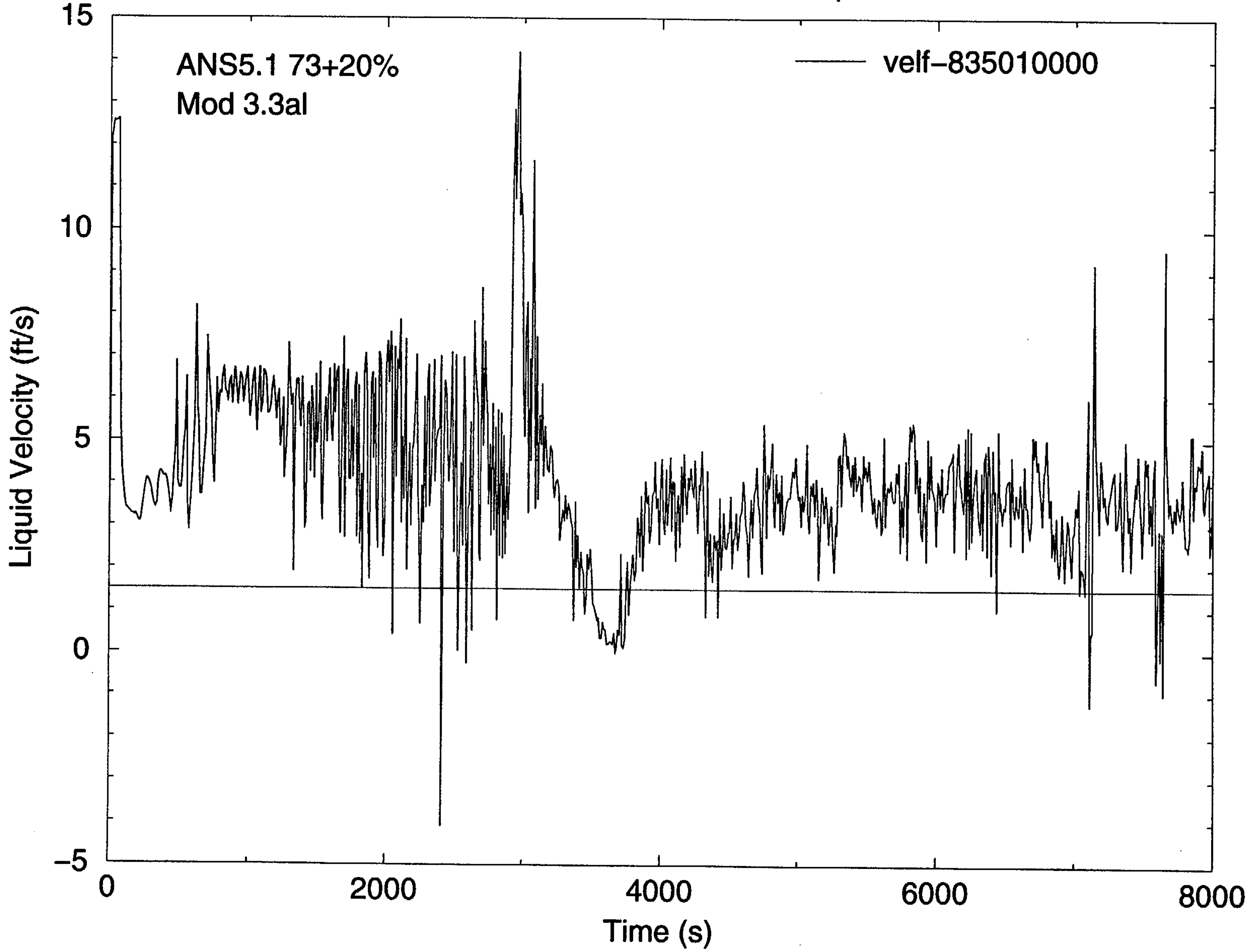

Break Flow Rate vs. Time
AP1000, 2 Inch CLB, DEC–Alpha
mflowj–376000000
ANS5.1 1973 +20%
ADS1a Failure
Mod 3.3al
Flow Rate (lbm/s)
Time (s)
0
200
400
600
800
1000
2000
3000
4000
5000

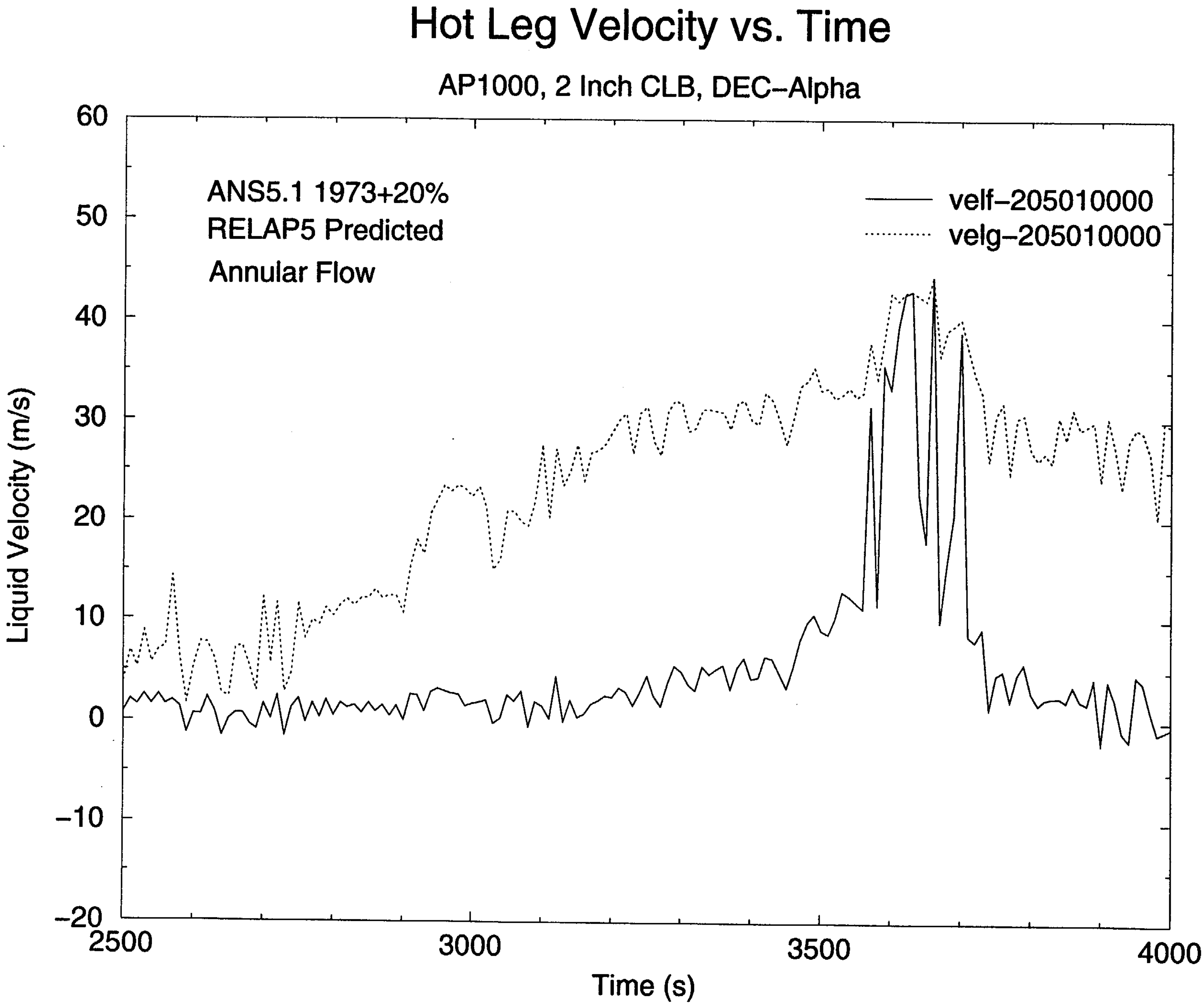
AP600 vs. AP1000 2in49 Break
Liquid Break Flow Rate



PRHR Exit Flow Velocity

AP1000, 2 inch CLB, DEC-Alpha





Hot Leg Velocity vs. Time
AP1000, 2 Inch CLB, DEC–Alpha
ANS5.1 1973+20%
RELAP5 Predicted
Annular Flow
velf–205010000
velg–205010000
Liquid Velocity (m/s)
Time (s)
60
50
40
30
20
10
0
−10
−20
2500
3000
3500
4000

NRC Staff Review of NOTRUMP and LOFTRAN for AP1000

ACRS Thermal/Hydraulic Subcommittee Meeting
February 15, 2002

Walton L. Jensen
NRC Staff

TABLE 1.0-2
Passive Safety System Design Features

System	AP600	AP1000	Comment
Core Makeup Tanks			Core makeup tank volume and flow rate is increased to provide additional injection flow. CMT elevations are maintained at the AP600 level.
Number	2	2	
Volume, ft^3	2000	2500	
Line Resistance, %	100%	64%	
Design Flow rate, %	100%	125%	
Accumulators			The accumulators remain the same as AP600
Number	2	2	
Volume, ft^3	2000	2000	
Pressure, psig	700	700	
IRWST			The IRWST level has been increased by using more accurate level instruments. This permits a higher operating level.
Volume, gallons	557,000	590,000	
Water Level, in	130.00	131.58	
Line Resistance, %	100%	32%	
Design Flow Rate, %	100%	184%	
Automatic Depressurization			The first three stages of ADS are the same in AP1000.
Stages 1-3			
Location	Top Pzr	Top Pzr	
Configuration	6 paths	6 paths	
Vent Area, %	100%	100%	
Stage-4			
Location	Hot Leg	Hot Leg	The ADS-4 vent area is increased more than the ratio of the core power. The ADS-4 venting is designed to allow for stable IRWST/sump injection during long term cooling
Configuration	4 paths	4 paths	
Line Size, nominal	10-inch	14-inch	
Vent Area, %	100%	176%	
Line Resistance, %	100%	28%	
Capacity, %	100%	189%	

TABLE 1.0-2
Passive Safety System Design Features
(con't)

System	AP600	AP1000	Comment
Passive RHR Heat Exchanger Type Surface Area, % Design Flow Rate, % Design Heat Transfer, %	 C-Tube 100% 100% 100%	 C-Tube 122% 174% 172%	The AP1000PRHR HX retains the AP600 configuration. The heat transfer area was increased by extending the length of the heat exchanger. The inlet and outlet piping have been increased resulting in higher flow rates.
Containment Diameter, ft Overall Height, ft Shell Thickness, 1A Design Pressure, psig Net Free Volume, ft^3	 130 189.83 1.625 45 1.73×10^6	 130 215.33 1.75 59 2.07×10^6	The AP1000 containment volume and design pressure were increased to accommodate higher mass and energy releases.
Passive Containment Cooling System Water Storage Tank Volume (Top of Overflow), gallons	580,000	800,000	The PCS water storage tank was increased to accommodate higher flow rates. The PCS flow rates have been increased based on the increase in core power.

LOFTRAN

- **Used to evaluate non-LOCA transients and accidents including SGTR in conjunction with other codes. (RCS pressure, fuel temperature, DNBR)**

- **Approved for operating plants 1985 and for AP600 1998.**

- **Entire reactor system is modeled but two phase conditions are only allowed in the pressurizer and upper head.**

AP1000 Considerations

- ADS actuation only for a limited period to assess DNBR following a spurious opening.
  No RCS void formation.

- PRHR heat transfer based on correlation of PRHR test data.
  Test conditions extend to those of AP1000.

- LOFTRAN cannot evaluate asymmetrical flow conditions in split cold legs.
  (Single RCP trip, locked rotor/sheared shaft)
  The external cold leg flow model developed for AP600 should still apply.

- CMT draining is not expected.
  No void formation expected in the pressure balance lines.

- Larger steam generators of AP1000 increase the likelihood that significant voiding may occur during MSLB.

NRC Staff Conclusion:

LOFTRAN is acceptable for analysis of non-LOCA transients and accidents for AP1000 including SGTR with the excepting one outstanding open issue.

Open Issue:

Westinghouse has not performed the analysis of a main steam line break to evaluate reactor system voiding. Voids might form in the reactor vessel head, CMT pressure balance line and intact steam generator tubes. The analysis and NRC review is deferred to Phase 3.

NOTRUMP

- Used to evaluate small break LOCA. NOTRUMP is used in conjunction with the SBLOCTA code to calculate peak cladding temperature.
- Approved for operating plants in 1985 and for AP600 in 1998.
- Five conservation equations and a drift flux model are used to calculate liquid and vapor flows and thermodynamic states.
- Momentum flux from area and density changes in the flow links is not included in the present model.

RELAP5 Comparisons

- **NRC RELAP5 input deck produced based on an existing AP600 input and information supplied by Westinghouse.**
- **Single failure, decay heat and containment back pressure same as NOTRUMP**
- **Higher core void fractions than for AP600**
- **Results similar to NOTRUMP**
  - **Differences in break flow and depressurization rate because of segmented downcomer modeling in RELAP5 vs. single stack in NOTRUMP**
  - **Slightly higher core void fractions than NOTRUMP**
  - **Slight core uncovery for DVI line break**
- **NRC approval of AP1000 to be based on Westinghouse calculations**

AP1000 Considerations

- Accumulators same size as AP600.
- ADS1/2/3 are the same size.
- CMTs are the same height but with 24% more volume than AP600.
- PRHRHX is 22% larger but removes 72% more heat.
  NOTRUMP has a high heat flow limit (tube flow <= 1.5 ft/sec)
- ADS4 is 76% larger and is designed for 89% more capacity. Entrainment of liquid including upper plenum and hot leg leading to the ADS4 is an open issue.

NRC Staff Conclusions:

NOTRUMP is acceptable for analysis of small break LOCA for AP1000 with exception to the following outstanding issues.

1. Liquid entrainment from upper plenum, through hot legs and ADS4. Westinghouse proposes to benchmark NOTRUMP ADS4 against a modified WCOBRA/TRAC. Experimental verification remains an issue.

2. The conservatism of the PRHRHX model needs to be justified for high heat flows. Westinghouse proposes to reduce the heat transfer area by 50%. This penalty needs to be justified in a data comparison.

3. Only a limited number of breaks have been analyzed. The results will be affected by resolution of the entrainment issues. If core uncovery is calculated, Westinghouse must seek approval for methodology used to calculate peak clad temperatures for AP1000 small break LOCA.

<u>W</u>GOTHIC Computer Program

Presentation to the Advisory Committee on Reactor Safeguards Subcommittees on Thermal-Hydraulic Phenomena and on Future Plant Designs

February 14-15, 2002

Edward D. Throm
Senior Reactor Engineer
Plant Systems Branch
Division of Systems Safety and Analysis
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Telephone: (301) 415-3153

WGOTHIC Computer Program

Evaluation of lumped-parameter network and circulation and stratification issues are discussed in

- WCAP-14407, Section 9
- NUREG-1512, Section 21.6.5.7.8

Application of GOTHIC program to international test problems, including the Battelle Model Containment (BMC) and the HDR (Heissdampfreaktor) experiments, demonstrated the conservative aspects of the lumped-parameter network.

Modeling conservatism to address uncertainties in circulation and stratification, and conservatism in the PCS flow and mass and heat transfer models resulted in the approval of an Evaluation Model for using WGOTHIC for design-basis accident analyses.

WGOTHIC Computer Program

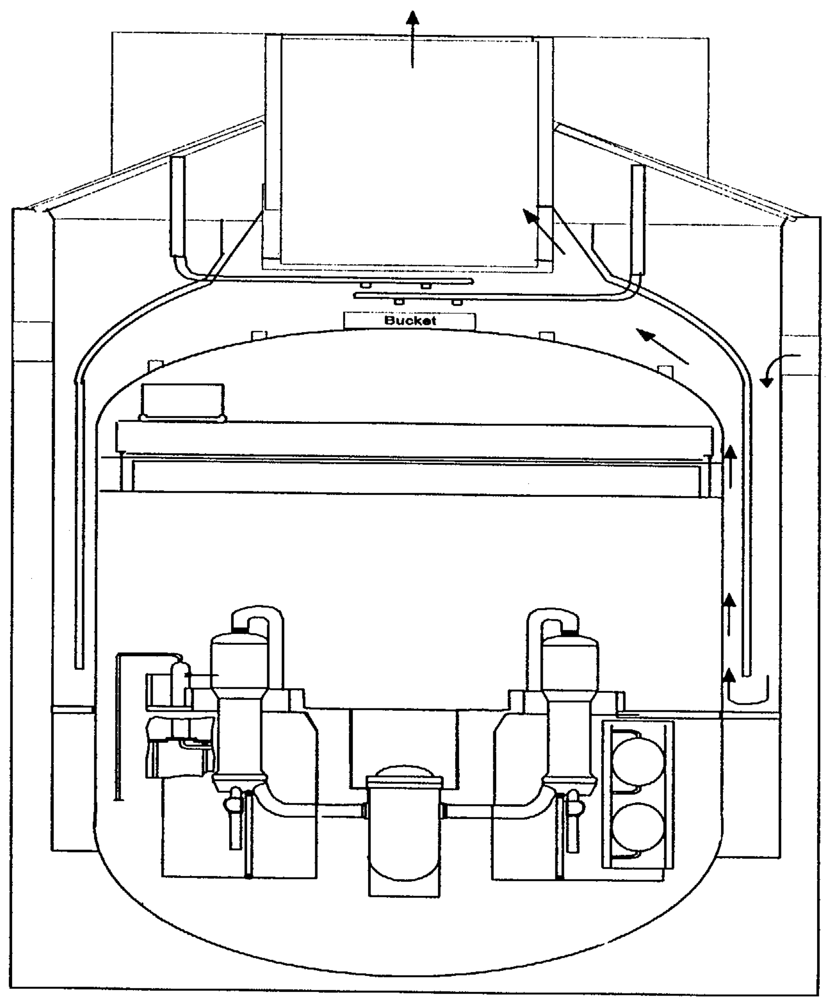
AP600 versus AP1000

Larger height could cause more complex recirculation patterns and influence mixing and increase the buoyancy driven flow rate. Less homogeneity of the containment atmosphere above the operating deck could result, with higher temperatures in the upper dome.

Westinghouse should conservatively predict any decreased homogeneity using the lumped-parameter model.

Scoping studied performed by Westinghouse indicate that the mass and heat transfer correlations are being used within acceptable ranges.

Figure 21.6-22. AP600 Containment



- The loss coefficient in the external annulus should include a 30 percent increase over the value derived from the test program.

- Condensation and convection on heat sinks in the dead-ended compartments, below the operating deck, should not be credited after the blowdown period. This conservative assumption should also be employed for MSLB analyses.

- Heat transfer to horizontal, upwards facing surfaces which may become covered with a condensation film is not credited. In particular, the operating deck itself, which becomes covered with an air rich layer, should not be credited.

For each calculation with significant energy transfer to the PCS through the shell, the stability of the "clime" heat and mass transfer solution must be examined by the COL applicant (for example by plotting heat transfer rates vs time for both the wet and dry "climes") to confirm that the calculation has not violated the time step stability.

In the "Evaporation Limited" flow model, Westinghouse neglects PCS runoff sensible heat which is conservative and offsets the nonconservatism introduced by the simultaneous use of the Chun and Seban and the "Evaporated Limited" flow model. Therefore, these two assumptions must be employed together, for the staff to consider this model to be acceptable for licensing analyses.

The 2-D enhancement to the "Evaporation Limited" flow may not be used to credit leakage reduction for siting evaluations.