Official Transcript of Proceedings ACRST-3189

NUCLEAR REGULATORY COMMISSION

ORIGINAL

Title: Advisory Committee on Reactor Safeguards
490th Meeting

PROCESS USING ADAMS
TEMPLATE: ACRS/ACNW-005

Docket Number: (not applicable)

Location: Rockville, Maryland

Date: Friday, March 8, 2002

Work Order No.: NRC-272

Pages 272-371

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UNITED STATES NUCLEAR REGULATORY COMMISSION'S

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

March 8, 2002

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

490TH MEETING

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FRIDAY,

MARCH 8, 2002

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ROCKVILLE, MARYLAND

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The Committee met in Room T2B3, Two White Flint North, 11 Rockville Pike, Rockville, Maryland, at 8:30 a.m., George Apostolakis, Chairman, presiding.

PRESENT:

GEORGE E. APOSTOLAKIS	Chairman
MARIO V. BONACA	Vice Chairman
F. PETER FORD	Member
THOMAS S. KRESS	Member
DANA A. POWERS	Member
VICTOR RANSOM	Member
WILLIAM J. SHACK	Member
JOHN D. SIEBER	Member

ACRS STAFF PRESENT:

MAGGALEAN W. WESTON

PAUL A. BOEHNERT

SAM DURAISWAMY

SHER BAHADUR

CAROL A. HARRIS

JOHN T. LARKINS

MICHAEL T. MARKLEY

C-O-N-T-E-N-T-S

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

(8:28 a.m.)

CHAIRMAN APOSTOLAKIS: The meeting will now come to order. This is the second day of the 490th Meeting of the Advisory Committee on Reactor Safeguards. During today's meeting, the Committee will consider the following; Phase II, Pre-Application Review of the AP1000 Design, Future ACRS Activities, a Report of the Planning and Procedures Subcommittee, Reconciliation of ACRS Comments and Recommendations and Proposed ACRS Reports.

A portion of the meeting may be closed to discuss Westinghouse proprietary information. This meeting is being conducted in accordance with the provisions of the Federal Advisory Committee Act. Mr. Sam Duraiswamy is the designated federal official for the initial portion of the meeting.

We have received no written comments or requests for time to make oral statements from members of the public regarding today's sessions. A transcript of portions of the meeting is being kept and it is requested that the speakers use one of the microphones, identify themselves and speak with sufficient clarity and volume so that they can be readily heard. I will begin by asking Dr. Kress, a member in this issue, to lead us through the Phase II Pre-application Review.

MEMBER KRESS: Thank you, Mr. Chairman. I remind the members that the application review for AP1000 is being done in three phases. Phase 1 was for Westinghouse and the NRC to identify what would be the key issues in the certification and Phase II was for Westinghouse to ponder those key issues and come to some sort of position on them. There are four of these basically and today that's what we're going to hear about, the four key issues and the staff's position on these.

And I think we'll be asked for a letter, of course, on our feelings about these issues. So, with that, I'll turn it over to Jim Lyons.

MR. LYONS: Thank you, Dr. Kress. I'm Jim Lyons, Director of the New Reactor Licensing Project Office and we're glad to be here this morning to discuss the completion of our review of the AP1000 pre-application review. We are getting ready to start the review of the design certification which Westinghouse is proposing to send in either later this month or, I guess, next month. We are looking forward to receiving your letter and with that, I'll turn it over to Larry Burkhart, who will make the presentation.

MR. BURKHART: Good morning, I'm Larry Burkhart, the AP1000 Project Manager and as has been said already, we're here to discuss the staff's assessment of the pre-application review. Phase II, the end of Phase II brings to a conclusion the end of the pre-application review.

Briefly, the agenda, obviously, introduction, what I am doing now, Mike Corletti from Westinghouse will give us an overview of the AP1000 design, with some highlights on the differences between the AP600 and that AP1000. We will provide our assessment of the four issues that were decided to be reviewed for the pre-application review. I'll talk about those details in a second.

We have staff from NRR and the Office of Research who were involved in that assessment and after our assessment, Westinghouse will give their presentation and their comments.

Some background; the AP600 was certified in December of 1999. About that time, Westinghouse expressed interest in applying for basically a larger version of the AP600, the AP1000, based on the AP600 design. Early in the year 2000, we discussed a three-phase approach that Dr. Kress mentioned. Pre-application review involved Phases 1 and 2. Phase 1, the scoping review, was completed in July of 2000 and Phase II is to be completed by the end of March, that's what we're talking about right now, and Phase III is the actual design certification review, which could come in as early as March, late March or early April.

So getting to the point of what we're here to talk about today, the scope of the Phase II review is limited to four issues; the applicability of the AP600 testing program to the AP1000 design certification review, the applicability of the AP600 analysis codes to the AP1000 design, acceptability of using the DAC approach in the INC control room and piping design areas and that's in lieu of providing detailed design, and acceptability of requesting certain exemptions that were granted for AP600. There are three exemptions which I'll talk about later.

The staff's assessment on these four issues will be documented in a SECY to the Commission and that would involve discussions of the design acceptance criteria, the DAC, and the other three issues would be documented in a letter directly to Westinghouse and both of these are on tap to be issued by the end of this month.

One last introductory slide, interaction we've had with Westinghouse, as you imagine, have been numerous. We had eight correspondences, which involved requests for additional information that actually covered 74 different questions. We issued those RAIs between January and October of 2001 and Westinghouse completed their answers to those RAIs by November of 2001. We've had several public meetings and tele-conferences and our interactions with the ACRS included a briefing on Phase 1 in August of the year 2000 and a couple weeks ago, three weeks ago, we briefed two subcommittees as listed on the slide on our assessments.

At that time our assessments were still not completely finalized, as you'll see in the discussion of design acceptance criteria. So moving on, I would like to turn over the mike to Mike Corletti, who will discuss the background of the design, philosophy of design for the AP1000.

MR. CORLETTI: Good morning. It's a pleasure to be here in front of you today. My name is Mike Corletti, with AP1000 Project. I have quite a few slides there in that package. I think I'm just going to try to highlight on a few of those, but they're there in case you have questions about the background of the design.

As Larry said, we are designing AP1000 to be based extensively on AP600 and to the extent that you see here is a comparison of the general arrangement of both AP600 and AP1000. And you will see, we are maintaining the design within the space constraints, within the general arrangement of the nuclear island. So the system configuration of the passive systems is the same as AP600 I'm going to show and here, we typically say to people, "Can you tell the difference between the two"? I think you'll see that the steam generators are larger but other than that from as far as the structural design here, there's not really much difference on this view.

However, when you go to a 70 percent upgrading, there are some changes that you have to make. Here's a good view of the -- a section view of the AP600 compared to the AP1000. The containment has been -- the height of the containment is increased approximately 25 feet basically to accommodate the larger mass and energy releases associated with the design basis accidents, and also to allow for steam generator removal, if necessary.

Here's a comparison of some key selected parameters. You'll see the power output, electric power output essentially 1117, which is more than 1,000 megawatts and we'd like to say that the 1,000 doesn't necessarily stand for 1,000 megawatt. That's $1,000.00 a kilowatt which is basically what we're designing the installed cost of AP1000 to be.

MEMBER POWERS: What is W 3XL?

MR. CORLETTI: The 3XL is the Dole and Tihange plants in Belgium. They are 14-foot core plants, 157 fuel assemblies. Pretty much this is the core, the reactor vessel that we've started with for AP1000 and I have comparison to AP600. AP600, if you remember, was a very low power density core. We essentially had a 1,000 megawatt reactor vessel and a 1,000 megawatt core and we were running it at 600 megawatts.

To improve economic competitiveness, we've basically taken the Doel Tihange core and as our basis for AP1000 and we have increased its rating to -- a comparable power rating to our operating three loop plants. You'll see some of the other key parameters. They both, AP600 and AP1000 uses a 17 by 17 fuel. As I said, we've gone to the 14-foot -- 14-foot active fuel length. One difference of AP600 and AP1000 compared to most operating Westinghouse PWRs is we use gray rods for load follow, so we don't use boron for load follow, which minimizes waste production.

CHAIRMAN APOSTOLAKIS: What did you say about the AP1000, what does 1000 means?

MR. CORLETTI: Oh, I'm sorry, that was our marketing. Typically, we started with 1,000 megawatts electro-power rating but you see the -- we've actually gone to 1117 but the driver for going from AP600 to AP1000 was to get a cost competitive product and where our U.S. utilities now are -- the target cost that we need to deliver on an overnight capital cost is essentially $1,000.00 a kilowatt, installed capital cost. This is our major driver for developing -- taking AP600 and developing it to an AP1000.

MEMBER KRESS: Tell me, what is it -- what is the need that drives the pressurizer volume increase?

MR. CORLETTI: The pressurizer volume increases there, to handle thermal transients, transients that would occur.

MEMBER KRESS: So it's thermal capacity.

MR. CORLETTI: Yes, and it provides basically a much more forgiving plant. AP600, you'll remember, is designed to the utility requirements document. One of those requirements was to eliminate the PORV function stemming from the Three-Mile Island accident. So the vendors all -- we've incorporated a larger pressurizer to mitigate these transients without opening -- without opening the safety valves, right, without the need for opening the PORVs.

MEMBER KRESS: So that's what takes the volume up.

MR. CORLETTI: That's what drives the sizing of the pressurizer and for AP1000 it even got larger. So it really provides a good operational benefit for -- to mitigate transients.

VICE CHAIRMAN BONACA: A couple of other things; at the surface area, there is a big increase over the hedge.

MR. CORLETTI: There's a big increase, right. The steam generator is what we call Delta 125 and it is similar to the -- it is based on the replacement steam generator that we had supplied for Arkansas but also essentially a small generator when you compare it to the CE type -- you know, the CE, System 2 type steam generators, where they fix their designs on two loops and with very large steam generators. This generator is within that size.

In the development of AP1000 shortly after we started, we had merged with Combustion Engineering and we really had the benefit of working with the

Combustion Engineering steam generator designers and the Westinghouse designers in bringing a larger generator within their operating -- it had been within their design experience.

VICE CHAIRMAN BONACA: The other thing I notice there, you have very similar core between the Belgium reactors and this but you have much less of reactor cool and pump flow.

MR. CUMMINS: Excuse me, this is Ed Cummins. When you compare steam generators and pumps to Tihange, you need to consider that there are three steam generators and three pumps in Tihange and two in AP1000.

VICE CHAIRMAN BONACA: Yeah, thank you.

MR. CORLETTI: Yeah, see the vessel flow is essentially the same.

VICE CHAIRMAN BONACA: Yeah, okay, right.

MR. CORLETTI: With AP1000 we have four pumps, four reactor coolant pumps.

VICE CHAIRMAN BONACA: The other one has three, all right.

MR. CORLETTI: Right.

VICE CHAIRMAN BONACA: That makes a difference.

MR. CORLETTI: So these are some of the

key parameters comparing AP600 and AP1000 in the reference plan.

Just quickly here, we see the reactor coolant system. As you'll notice, it is two loops but four reactor coolant pumps which is a different configuration than the previous Westinghouse plants. As I said, the reactor vessel is based on the 3XL. It's the same outside diameter as AP600 but is a longer vessel. The Delta 125 steam generators, the use of canned motor pumps which is based on our naval applications, a very high, reliable canned motor pumps, eliminate seals, no seal injection, no need for seal support.

Simplified main loop piping, eliminate the cross-over line. This elimination of the cross-over line improves a small break LOCA performance is one of the inherent features of the AP600 and the AP1000.

VICE CHAIRMAN BONACA: How do you deal with the coast down?

MR. CORLETTI: For the reactor coolant pump, for the Navy applications, they have a very -- do not worry about coast down. For AP600 we designed a high integrity fly wheel, we built it and tested it and we've incorporated that in this design.

VICE CHAIRMAN BONACA: Okay, a fly wheel.

A VOICE: It's depleted uranium, right?

MR. CORLETTI: The -- it is constructed of depleted uranium. It is totally sealed.

MEMBER POWERS: Why a 60-year design lifetime and not 80?

MR. CORLETTI: Well, the regulations only allow us 40 at this point in time. We've designed it for 60 --

MEMBER POWERS: And you're going to go for 20.

MR. CORLETTI: Perhaps 70 years from now we'll be talking about plant life extension.

MEMBER KRESS: And big steam generators let you go to a power upgrade.

MR. CORLETTI: Right. You go into high burn-up fuel, I'll tell you that.

What you see here is the passive decay heat removal heat exchanger. This is one of the key features of the passive safety systems. It is used to mitigate transients. It replaces essentially the safety grade emergency feed water and ox (phonetic) feedwater. So it's designed for events like a loss of normal feed. The passive heat exchanger is located in the refueling water storage tank, inside containment. It's located above the core on a low steam generator water level. Valves are actuated and by natural circulation, the heat exchanger provides core decay heat to mitigate any of the transients that were designed for.

MEMBER KRESS: Does the water boil there in the transient?

MR. CORLETTI: Yes, the IRWST, the heat capacity is such that after about an hour and a half of continued operation, the tank would begin to boil, but with the passive containment cooling, where condensate then is condensed on the steel shell and returned to the IRWST, the passive decay heat removal can provide core cooling essentially indefinitely.

MEMBER KRESS: Is there a pump that takes that back or is it gravity?

MR. CORLETTI: No, it's by gravity. The -- it's got an arrangement on the containment shell that returns the condensate back to the refueling water storage thing.

MEMBER KRESS: That's just like the AP600.

MR. CORLETTI: Exactly like the AP600. Now, the heat exchanger has been increased in surface area roughly 20 percent. How we've -- we've kept the capacity though in relation to the core power and we've achieved that by making the inlet and outlet piping a larger diameter so that reduces the resistance to the natural circulation driving head and we've been able to maintain a capacity about the same factor as the core power. Because this is designed to remove core decay heat, we had to maintain that sort of a --

MEMBER KRESS: These two valves --

MR. CORLETTI: Those are fail open air operated valves, yes, and they receive a signal on low steam generator water level. Again, with AP600 and AP1000 with defense in depth, we typically have non-safety active systems which is the first line of defense. You would have a loss of normal feedwater. The start-up feedwater pumps would be actuated to supply feed water to the generators.

If they would then fail, then the passive decay removal heat exchanger is actuated.

MEMBER KRESS: Now, you indicate that the four-stage ADS comes out of that vertical line. I thought it came out of the hot leg.

MR. CORLETTI: It shares a connection. The ADS 4 on that loop is actually -- is t'd off of this inlet line.

MEMBER KRESS: T'd off of this line.

MR. CORLETTI: Yes. So it is connected to the hot leg, it's very close coupled to the hot leg.

MEMBER RANSOM: At one time there was a concern about the ability to model the heat exchange and the vertical heat exchanger tubes. Were any experiments done to verify the --

MR. CORLETTI: Yes, as part of AP600, we did a full height, full pressure, full temperature tests of vertical tubes to develop a heat transfer correlation which we then validated our analysis codes to that heat transfer correlation and also demonstrated it with blind tests at the Rosa facility which is one of the test facilities that was conducted by the NRC and we had very good predictions of heat transfer using that correlation.

MEMBER KRESS: Now, what's the issue then with thermal plume there?

MR. CORLETTI: There is a -- the staff had asked questions in regards to are you able to have steam blanketing on the outside of the tubes. We essentially showed that for the tests that we ran and for the tests at Rosa that really that our heat transfer correlation which is based on a modified Rosenal (phonetic) correlation, was sufficient to predict overall heat transfer.

I think the concern they had was could it degrade the heat transfer of the heat exchanger? And I think that we showed that through our tests and through -- we did several sensitivity studies where we --

MEMBER KRESS: Well, I recall in one of the presentations or something that I read that if the velocity exceeded a certain level, you had a problem with that.

MR. CORLETTI: Okay, that is a -- that question is specific to the no trump code (phonetic), the LOCA Code. There was an issue there that for the correlation that we use in the NOTRUMP code, if the velocity was too high, it could be non-conservative. For AP600 the velocity was not in the non-conservative region but there is an issue, with AP1000 with the higher flow rates, will your correlation --

MEMBER KRESS: Will you get into that?

MR. CORLETTI: Right, and what we're going to have to do there as part of -- as part of design certification is provide -- is take -- essentially adjust that heat correlation so it is not -- so it is no longer non-conservative with respect to our test data.

And I think what the staff is requiring us to do is provide a justification for that modification to that correlation. So we will plan on doing that as part of the --

MEMBER KRESS: The correlation is HA times a delta T. My understanding was you're going to adjust the A.

MR. CORLETTI: Right.

MEMBER KRESS: But since it's a product of HA, it doesn't --

MR. CORLETTI: Right, that's right and this is only for the NOTRUMP code.

MEMBER KRESS: And under certain --

MR. CORLETTI: For the loss of coolant accident which really the passive chart is not a big -- you know, it's not dominate in the loss of coolant accidents. For the transients, there we've used the modified Rosenal correlation that we based on our test data. That's not a concern there.

MEMBER KRESS: It's okay, there.

MR. CORLETTI: Yes.

MEMBER KRESS: And that's in -- what code is that?

MR. CORLETTI: That's in the LOFTRAN code.

MEMBER KRESS: The LOFTRAN, okay.

MR. CORLETTI: Here you see the passive safety injection system for the AP600. I think this is probably familiar to most of you, but the features of passive safety injection, the accumulators, we have two accumulators that are exactly the same for both 600 and 1000 and they're really sized to mitigate the large break loss of coolant accident. Their size is consistent with our operating plants today.

You have the core makeup tanks which are aligned at very high pressure in case of a leak from the reactor coolant system and they're able to provide high pressure injection. They replace the high head safety injection function in today's plants. They also provide boration capability to mitigate steam line breaks.

We also have the refueling water storage tank which is there and we're going to be talking a little bit more later to provide long-term safety injection. As the pressure is reduced following the loss of coolant accident, as the core makeup tanks would drain, automatic depressurization valves connected to the pressurizer designed to reduce the system pressure to allow gravity injection from the refueling water storage tank.

The final stage of depressurization is achieved with the four-stage valves which are connected to the hot leg and how we've differed the design from the AP600, essentially the same configuration has been maintained. We've maintained the same elevations. The core makeup tanks are increased approximately 25 percent and the line resistance has been reduced to increase their flow rates about 25 percent.

The low pressure portion, low pressure injection portions of the system, including the ADS stage 4, and the IRWST injection lines and the sump injection lines have all been increased to -- in relationship to core power to accommodate the higher core power associated with those.

MEMBER KRESS: What does FAI stand for on that?

MR. CORLETTI: That's a fail as is valve.

MEMBER KRESS: Fail as is.

MR. CORLETTI: That's what that means, yes. Those are -- those four-stage valves are Squib valves. They're explosively operated valves that operate one time type operation. When the core -- following the loss of coolant accident, after the core makeup tank has essentially been emptied. So you've had a very large loss of coolant accident.

MEMBER KRESS: What causes the signal?

MR. CORLETTI: On a core makeup tank?

MEMBER KRESS: There's a level signal?

MR. CORLETTI: Yes, there's a 25 percent level signal, 25 percent level in the core makeup tank.

MEMBER KRESS: And it's explosive Squib valve that once it goes, it's opened.

MR. CORLETTI: Yes, it opens, it opens.

MEMBER KRESS: And the steam just goes into the containment there.

MR. CORLETTI: Right, I think my next slide, for all accidents, we use passive containment cooling, so for an accident like a steam line break or a loss of coolant accident where steam is released into containment. Water tanks at the top of containment there we have a line that opens. We pour water on the steel containment shell. There enters these baffles that you see on the shield building and down and pass over the containment shell and by evaporative cooling, provide containment cooling to mitigate all design basis accidents.

MEMBER KRESS: That feed line from the water tank, it has a valve in it that's not shown here?

MR. CORLETTI: Yes, in fact, for AP1000 we actually have added a third -- there's actually three lines, so as part of our PRA studies, we've added a third diverse line for passive containment cooling.

MEMBER KRESS: Wide open so --

MR. CORLETTI: Those valves open on high containment pressure or high containment temperature.

MEMBER KRESS: Okay, that makes sense.

MR. CORLETTI: The tanks on --

MEMBER KRESS: And where are those measurements made?

MR. CORLETTI: Those are made from instrumentation inside containment.

MEMBER KRESS: You mean, you have a bunch of them redundant?

MR. CORLETTI: Yes, redundant, redundant, at least, I believe we have four, four containment pressure measurements.

The tank is sized for three days of containment cooling flow. After three days we would have water tanks and the dedicated pump to provide water to replenish the tanks to provide core cooling but even after -- on AP600 after three days, our studies showed that air cooling was sufficient. Air cooling is also sufficient to keep containment pressure below the service level cease limits for the containment.

MEMBER KRESS: Now, these are based on your separate effects test with the large containment vessel?

MR. CORLETTI: Well, yes, we performed a slew of separate effects tests as far as basically to get heat transfer correlations to apply for the passive containment coolant, heat transfer correlations for heat transfer across the containment shell. Essentially, we've used them in a steady state heat transfer correlations.

MEMBER KRESS: Right.

MEMBER POWERS: Where are those documented?

MEMBER KRESS: There was a test basis document that --

MR. CORLETTI: Right, for AP1000 we submitted a test applicability -- I mean, our applicability document that went through all of the test programs for AP600 and showed how they were still applicable for 1000. For AP600, we had -- there's several different tests, either test reports or the final validation report for Gothic which the Gothic report showed the validations of the tests.

MEMBER KRESS: We got all those when we reviewed AP600.

MR. CORLETTI: Right.

MEMBER KRESS: I don't know if we still have them or not. I've got --

MR. CORLETTI: You know, there were several reports.

MEMBER KRESS: They might have just been sent to the Thermal Hydraulics Section.

MEMBER POWERS: None of this is very hopeful because there's a mountain of information here. Could somebody point me toward where all this stuff is?

MR. CORLETTI: Sure.

MEMBER KRESS: Well, we'll get -- these are sort of just for our information now because we'll get a chance to go over all this again when we talk about the recertification. This is just to orient us more or less. I don't think there's any decisions that have to be made regarding these things at this point.

MR. CORLETTI: Yes, right. I think during the review the crux of the review from this issue was that were the tests that we performed for AP600, was AP1000 still within the range of those tests that were performed.

MEMBER KRESS: Yeah, that's the issue,

that's the issue.

MR. CORLETTI: And I think the staff's going to report on their findings on that.

Just a couple slides just showing some of the performance of the passive systems. You'll see, here's a comparison for a large break LOCA showing the large margins that the passive plants provide for mitigation of a large break.

For AP600, peak clad temperature was less than 1640 degrees fahrenheit. For AP1000 it will be higher but we will be well within the regulatory limits for it. Essentially, here the dominate phenomena is not the passive systems, it's really the accumulators and the core-stored energy.

This slide here shows a comparison for small breaks, for small break LOCA margin. One of the key features of the passive safety systems was that the improved performance for small break where we would not have core uncovery for these events, for our current PWRs, for two-inch, three-inch sized breaks where they're limited on safety injection flow typically you would have a fairly decent, fairly significant heat-up, still under the regulatory limits.

Here you see for the passive plants

essentially you have no core uncovery for the range of small breaks. A couple others I just will real quickly go; this just shows a comparison of our PRA. This is another one of the benefits of the passive systems, you see very low risk margins for AP600. We expect AP1000 to have similar results.

MEMBER POWERS: I'm unfamiliar with the requirement for -- NRC requirements. What are you referring to there?

PARTICIPANT: The one times tenth to the minus four core damage frequency for initiating events.

MEMBER KRESS: It don't think it's a requirement.

MR. CORLETTI: Probably it's a guideline, I think. It's probably not a requirement.

MEMBER KRESS: Yeah, a guideline is a better word.

MR. CORLETTI: Yes, I think that's fair. And this last slide really shows you a comparison of the size of the 600 compared to an evolution style plant, I'm sorry, AP1000, compared to an evolutionary plant. This is Sizewell. And you see with the passive systems, that we've been able to achieve a much simpler design and a much smaller plant footprint because due to the modular construction the plant, the whole plant is designed in modules and very much smaller footprint than those in the past, such as the Sizewell.

MEMBER KRESS: What's the power of Sizewell?

MR. CORLETTI: Sizewell, yeah, we are cheating a little bit there, about 3800 megawatts thermal, we're 3400 megawatts thermal.

MEMBER KRESS: Not that much difference.

MR. CORLETTI: Yeah. I think Larry talked about the scope of Phase II of this pre-certification review that we've just finished and I think the four major questions that we were looking to answer in regards to the applicability of our test program that we completed for AP600, as we said, we completed a very thorough test program that was extensively reviewed by ACRS and the staff. We're looking to see the applicability of that test program to AP1000.

And also then the AP set of analysis codes that were validated against those tests, we plan on using those codes too, in the design certification for AP1000. And then the other two issues, the one is on the issue of the use of piping design acceptance criteria and the issue of the exemptions approved for AP600.

That's all I have. I think I'm going to turn it over to the staff now.

MR. BURKHART: Dueling slides. You've seen this slide before. It's not a new one. It reflects what Mike just stated as the scope of review and here we'll start the staff's assessment. I will discuss the applicability of the exemptions and the DAC approach and Steve Bajorek from the Office of Research, will discuss the applicability of the AP600 testing program and Ed Throm and Walt Jensen from NRR will discuss the analysis codes.

PARTICIPANT: Do you have copies of these slides, sir?

MR. BURKHART: Yeah, this was a previous slide I had in my introduction. Okay, exemptions, the applicability of the exemptions; the three exemptions that Westinghouse plans to request for the AP1000, this is a rundown of what the requirements are. Section 50.34 (f)(2)(iv) additional TMI related requirements regarding technical information contained in application requires the safety parameter display console, 50.62, requirements of the reduction of the risk from ATWS requires diverse and automatic initiation of auxiliary feed water, emergency feed water and the third GDC 17 which requires two physically independent offsite power sources.

A little more information added on this slide, based on the design, the passive design of the AP600, mostly, these exemptions, the request for exemptions were granted for the AP600 and based on meeting the special circumstance, that application of the regulation is not necessary to achieve the underlying purpose of the rule. And based on our review, we believe that due to the similarity in design between the AP600 and AP1000, that it's appropriate to ask for these exemptions and expect that they will be justifiable and the exemptions are basically applicable. We will do the complete detailed review during Phase III, the design certification review.

Design acceptance criteria; I'd just like to go over the requirements and how we've used the design acceptance criteria approach in the past in design certification reviews. The requirement in Part 52 is as stated; "An application must contain a level of design information sufficient to enable the Commission to judge the Applicant's proposed means of assuring that construction conforms to the design and to reach a final conclusion on all safety questions associated with the design before the certification is granted".

Not a prescriptive requirement, but pretty clear on the intent. And after Part 52 was issued, there were issues that came up on the level of detail that was being provided in the ABWR and the System 80+. And where we start to get some clear direction and guidance on the use of the DAC approach was in SECY-92-053 and this is again during the review of the System 80+ ABWR. The staff observed that applicants weren't providing the level of information that we thought we would get and this is where the DAC approach first was discussed.

And the DAC, Design Acceptance Criteria, are defined as, "A set of prescribed limits, parameters, procedures, and attributes upon which the NRC realized in a limited number of technical areas that making a final safety determination to support a design certification". And it was conceived that, you know, this concept would enable the staff to make a final safety determination as required by Part 52, subject only to satisfactory design implementation, verification by the combined licensee for appropriate use of inspections, tests, analysis and acceptance criteria.

And the staff concluded that you should restrict the use of DAC to two cases where a design area is characterized by rapidly changing technology and thus, if you finalize a design at the design certification phase, it may be obsolete by the time a plant is actually built or design areas for which as-built or as-procured information was not available.

And how we use it in design certifications, for the ABWR the System 80+, we approved the DAC approach for the I & C and control room or human factors engineering areas due to the rapidly changing technology aspects. We also, for both of these design certifications, approved the DAC approach for the piping and radiation protection areas based on the lack of as-built or as-procured information being available.

MEMBER KRESS: So you were able to approve the piping DAC for ABWR and System 80+ without it being a safety issue apparently.

MR. BURKHART: Correct, we were able to come to a conclusion on all safety questions, right, as required by Part 52.

MEMBER KRESS: And you feel like you can't do that with AP1000?

MR. BURKHART: We're getting to that.

MEMBER KRESS: Okay.

MR. BURKHART: Our conclusions may be a little bit different than what we discussed back in February.

MEMBER KRESS: Okay.

MR. BURKHART: Okay, so chronologically moving on to the AP600 design certification review, we allowed the use of DAC in the I & C and control room areas just as we did for the ABWR and System 80+, same reason. However, piping back was not requested and it wasn't used. And even though the as-built or as-procured information wasn't available, Westinghouse completed the piping design and they basically assumed that information.

The DAC approach as proposed for the AP1000, a little history here; originally, Westinghouse proposed or it was discussed that DAC, the DAC approach would be used in the I & C, the control room, the piping, the structural and the seismic areas for hard rock and non-hard rock sites. And that was definitely expanding the use of DAC as compared to what we had done before. And we had some discussions with Westinghouse on our ability to come to conclusion on all safety questions due to coupling all of these together, especially the piping structural and seismic areas.

We had some conversations and some public meetings and voicing our concerns, and basically on February 13th, Westinghouse revised their proposal for the use of DAC to limit DAC in the I & C, control room and piping areas. They would basically provide sufficient information to preclude the use -- the need to use DAC in the seismic and structural areas and in that same letter, they provided more information supporting why they should be able to use DAC in the piping area.

So our assessment, we think the DAC approach is acceptable for the I & C and control room design areas, the same reason as we approved it for the previous three design certifications, rapidly changing technology. In the piping area, we do recognize that Westinghouse completed the piping design in the AP600 and due to the similarity, we think there will -- we will realize the benefits of standardization that they'll carry over from the AP600 to the AP1000 due to the similarity.

Westinghouse noted in their February 13th letter that it gained very little regulatory benefit by performing a detailed piping design because they were still subject to pretty much the same ITAAC as the ABWR and System 80+. And due to the similarities in design, we find that the completed AP600 piping layout and design provides a sufficient level of detail to assure that the benefits of standardization will be achieved for the AP1000 piping.

MEMBER RANSOM: I have one question on the instrumentation and control, are these hard wired plants, or have they gone to fiber optic pipe systems?

MR. BURKHART: Mike, do you know the answer to that?

MR. CORLETTI: Yes, we do use a digital I & C. We are hard-wired from the sense of to the data highway but we have gone to the digital.

MEMBER RANSOM: So you have two independent systems then?

MR. CORLETTI: We have three actually. We have a safety related protection monitoring system. We have the plant control system and we have a diverse actuation system which is digital also but is diverse to the protection system and it provides certain protection type functions.

MEMBER RANSOM: Thank you.

MR. BURKHART: So based on the arguments on the previous slide, we find that the piping DAC approach is acceptable for the AP1000. However, just as with any DAC, it's contingent upon being able to agree with Westinghouse on adequate DAC. Again, that's for any design acceptance criteria used. There will be changes in piping size and we will have to identify areas of concern. We think we can -- we can be able to make -- come to a conclusion on all safety questions but there are some areas where some changes may cause us to focus, again, areas for Phase III, design certification review and some of those areas are listed here.

Now, the impacts of using design acceptance criteria; it has a potential to increase the likelihood of post-construction hearing petitions, and to expand the scope of a hearing. Compliance with a DAC can be subject of a hearing just prior to operation, including those DAC that were intended to be verified early in the construction process.

MEMBER KRESS: In other words, you're moving towards what you used to do when you had to have a construction permit and an operating permit.

MR. BURKHART: A little and I do want to say that we're -- with allowing pipe DAC for Westinghouse, we're not expanding the use of DAC compared to what's been used before.

MEMBER KRESS: Because you did it before.

MR. BURKHART: Because we did it before. In fact, Westinghouse -- well, ABWR and System 80+ used it for radiation protection. They're not using it in this case. So the reason for approving the piping DAC is a bit different than the reason we use for approving the DAC approach for the ABWR and System 80+. That was, again, for as-built or as-procured information not being available. We think because of all the work that's been done on the AP600 and the similarity of the design between the 600 and the 1000, which the exact extent of that similarity will be determined in the Phase III review, but because of the work that's been done and the degree of standardization we'll probably get from the AP600 design, that's why we're finding it acceptable for the AP1000.

Well, that concludes the assessment of the exemptions and the design acceptance criteria. Now, Steve Bajorek from the Office of Research, to discuss the staff's assessment of the applicability of the AP600 testing.

MR. BAJOREK: Okay, thank you, Larry. Good morning, my name is Steve Bajorek. I'm from the Office of Research. What I'm going to talk about hopefully over the next 20, 25 minutes or so is the research evaluation of the test programs that Westinghouse is using for the AP1000 and that were done primarily in support of the AP600. As Larry and Mike Corletti mentioned, as part of the AP1000 application, Westinghouse has proposed to use the test programs that were used for the AP600 in support of all of the data needs for the AP1000.

Their contention is that the data from the AP600 programs is adequate. It's sufficient and it covers the range of conditions that one would expect for accident scenarios in the AP1000. The research role was asked to come in and for those tests that effected the primary system, evaluate those tests, perform an independent evaluation and come up with our own opinion on whether that data is truly acceptable.

What we did is we broke our evaluation up into what I would consider three overall segments. One, which I'll refer to as a top down scaling approach which takes a look at the major interactions of the system between other subsystems, how it interacts with safety systems and how the system behaves as a whole. We supplemented that with simplified calculations. You might think of a first principles thermodynamic evaluation looking at the

RCS, the flows into and out of the system in order to get a better handle on the transient behavior as the AP600 or AP1000 transitions from its high pressure performance as the ADS 1/2/3 are on all the way through to the IRWST injection phase.

Finally, we did another evaluation that has been referred to as a bottom up scaling approach that looks at those individual two-phased processes that you really can't address very well, either with simplified numerical calculations or in the top-down scaling approach which really homogenizes everything that goes on in the system.

You could spend a couple of days just going over different top-down scaling methodologies and what they entail. Essentially, what is done in a top down scaling approach is to look at the mass momentum and energy equations for a particular flow circuit in a system and non-dimensionalize those and then you look at those non-dimensional terms which appear in front of each one of the major components of that mass momentum or energy equation. This gives you a set of dimensionalist groups, what we would refer to as pi groups that you can compare from one facility to the next and make a decision if the important processes in the AP600 or the AP1000 are those same things that occurred in the major integral test facilities.

MEMBER KRESS: Let me ask you a question about that. When you take these pi groups, you ratio the -- say from 1000 to the test or to 600 and you say that if that ratio for any one of these umpteen pi groups falls in a range of .5 to 2, then that's an acceptable range so that the phenomena you would expect to be the same. My question is, how did you arrive at that range and why is it -- why is it the same range for every pi group ratio?

MR. BAJOREK: It necessarily isn't the same range for every pi group. Let me just briefly describe the overall approach.

MEMBER KRESS: Okay.

MR. BAJOREK: It's to take a look at these dimensionless groups and if you -- the ratio of those is between .5 and 2. Essentially, if everything is within an order of magnitude it was deemed acceptable. Now, in answer to your question on where I got that, I got that from the AP600 review, used that as an acceptability criteria. It was the tighter of the acceptability criteria that was used. In some cases it was between .3 and 3. Now, we didn't just base our conclusion on all pi groups falling within that range.

Indeed, if you take a look at the test, some of them fall without that, outside of that range. We independently evaluate each one of those groups to come up with a determination; one, is it really important to the problem. In the INEL methodology that we applied, one of the nice features is that the pi groups are such that ones with very large values are indicators, these are important. Ones with very small values are effectively unimportant.

So when we looked at those --

MEMBER KRESS: That's like saying it's a coefficient multiplying something that determines the influence of that something in the equation. And you know, I think it's both the size of the coefficient and the something that determines. I mean, you have to have -- you can't look at the coefficient by itself.

MR. BAJOREK: Okay. I guess, you know, the best I can say is we tried to follow what was done in the AP600. We stayed on the tighter side of that criteria. And when we did this we looked at things. If they were outside of the range and distorted, we tried to come up with a rationale, did it really matter? And if it didn't matter, or if they were such that the process in the AP1000 was going to be more benevolent, have more mass in the system, behave better than the tests, then you would assume that that distortion was a conservative one and it would be acceptable.

A real concern are those things that we could identify as being very important to how the AP1000 behaves and were not represented well in the experiments. And usually, I think we would fine in these scale groups they were fairly close to 1, 1.2, 1.3.

MEMBER KRESS: And those things came out of the PIRT?

MR. BAJOREK: Yes, yes, or they fell outside of that range. If we changed that range a little bit, we would come up with essentially the same conclusions. So I think that, yes, we did look at the sensitivity to that and things that we will identify as being important we think would fall outside of an acceptability criteria even if you made it much looser.

Okay, with respect to the top-down scaling, the news is basically good here, in the use of the AP600 integral tests. We looked at two different scenarios, a one-inch cold leg break, a double-ended guillotine of a DVI line, which tends to be perhaps the most important of the transients, looking at small break processes and we found that for five -- four of the five major periods of the small break and a long term cooling transient, tests that were done in support of AP600 cover what we would expect for the AP1000.

I show here on these bullets the five different periods. Early in time, we see that the AP1000 scales very well with SPES. In fact, AP1000 scales better with SPES than the AP600 did based on the changes that were made to the system. If you go further out in time, there weren't a tremendous amount of changes that were made effecting the IRWST. The sizes were larger but elevations which effected driving heads didn't change that much, so again we reached the conclusion that AP1000 scales fairly well with APEX, the facility at OSU for the late phases.

Now, we do have what I might call a difference of opinion with Westinghouse on the one phase that transitions from high pressure to low pressure. I refer to this as the ADS-4 blowdown. Westinghouse claimed in their submittals that APEX, the OSU facility, was valid and that data was good throughout that period. When we do our scaling evaluation we find that APEX starts to fall just outside of that acceptability range but SPES remains within that range.

So with regards to the test programs, we would conclude, yes, the tests are available. During this period we think SPES is probably the better one to base your conclusions on code accuracy as opposed to APEX but once you get down to lower pressure, APEX, again, becomes the facility that you should base your decisions on.

MEMBER KRESS: Is this one of your bottoms- up scaling?

MR. BAJOREK: No, this is a top down.

MEMBER KRESS: This is top down.

MR. BAJOREK: This is top down.

MEMBER KRESS: So you're dealing with the momentum and energy equations.

MR. BAJOREK: Yes, yes.

MEMBER KRESS: And what pi groups come out of that? Are they --

MR. BAJOREK: Essentially --

MEMBER KRESS: Froude number?

MR. BAJOREK: Well, in this one it is a -- well, there's actually about 65 to 70 scaling groups.

MEMBER KRESS: Total, yeah, so they don't all apply to APEX.

MR. BAJOREK: Total. They don't all show up in each one of the periods. They change as you go throughout. The Froude number and things like that, that's for bottom up and we'll get to that in just a second.

Now, one thing that we do note with the ADS-4 blow-down and this is perhaps more of a critique on the methodology itself, is it does make some assumptions on what goes on in the tests and in the AP1000 and one of those is that you have a certain exit quality leaving the ADS. We stayed consistent with the methodology. We didn't want to invent anything new at this point but we did note that during this period, those assumptions and the scaling groups are relatively sensitive to your assumption in what is that flow quality? How much liquid is leaving during this period. And we thought, well, this is something that means we should look at it in a little bit more detail.

We continued with the bottom up --

MR. CORLETTI: Steve, could I just make one comment? This is Mike Corletti, Westinghouse. In regards to our code validation, we did validate our codes to both APEX and SPES and typically we wanted to have at least one of the facilities be well-scaled in all of the regimes, so we did actually have acceptable validation for one well-scaled facility for AP1000, even.

MR. BURKHART: That's right and that's basically what my conclusions say. Based on top-down, you don't need any more data. It may be how we look at what validation you did that's the determining factor in how good the code is doing. But we went on and we still want to look at the bottom up processes. As part of that we set up a simplified model. It looked that the RCS essentially is one node, takes the mass equation, the energy equation and sets up essentially a thermodynamics problem to look at the shrink and swell of the phases, the flows into and out of the system.

The conclusion that we get out of those calculations is that regardless of what we assumed for exit quality out of the ADS, the pressurization of the system didn't change all that much. Now, that's important because it says the delay time between when you have CMT flow and that essentially stops and you're waiting for the IRWST to come into the system, that period of time stays about the same. But what the sensitivity also showed us that we would very drastically reduce the mass in the vessel, in the

AP1000 relative to the AP600 or the experimental facilities at a rate at which suggested maybe we're going to see some core uncovery because of this uncertainty in the exit quality through the ADS.

That starts to point at things in a bottom up evaluation. It says, well what would contribute to a high amount of flow leaving the system, things like entrainment in the vessel and in the hot leg. So this starts to support some of our conclusions in the bottom up scaling where we look at precisely those phenomena that get missed in a top-down scaling.

And these are things in two-phase flow which tend to act as cliffs, flow regime transitions. Are you homogenous or are you stratified or annular? Are you flooding in the surge line or are you not flooding in the surge line? Entrainment is another process by which you have a gas flow, there's no entrainment. Higher gas flow, no entrainment. Suddenly you reach a critical point and you have a great deal of entrainment. So we looked at the bottom up processes for flooding, flow regime transition and again, I think the message should be that the news is really quite good here because when we looked at regime transition, flooding, core level swell and void fractions again, they're not too far off from the ranges that we saw in the AP600 tests.

The exceptions, the things that start to stand up as important items to look at in Phase III are two-fold. Both are related to entrainment; one in the hot leg. The other I'll refer to as a pool type entrainment. And this is entrainment that occurs at the top of the core, between the top of the core and the upper plenum.

MEMBER KRESS: Now, did any of the tests have a way to determine what that particular entrainment was?

MR. BAJOREK: Yes.

MEMBER KRESS: You were able to get that out of some --

MR. BAJOREK: Yes, I'll jump ahead a couple of overheads, but after the AP600 tests were completed, the NRC ran what they called no reserve tests. Now, these were tests in which you had mass in the upper plenum, they turned on the power, evaporated and swept out that liquid. It showed from the test results that there was an unexpectedly high amount of entrainment from the upper plenum pool.

MEMBER KRESS: You could compare the level change with the amount of energy going in and if it wasn't going out as steam --

MR. BAJOREK: It was going out as liquid and they used the separator tanks also to catch that.

MEMBER KRESS: I was going to ask you, you could catch it.

MR. BAJOREK: Yes.

MEMBER KRESS: Okay.

MR. BAJOREK: Now it wasn't a primary focus in the APEX tests that were run integrally for looking at one-inch cold leg breaks and you can't really get it out of those. There's too many things going on. But in these no reserve tests, they noted, yes, this is a process that was going on and what became bothersome is that RELAP calculations, simulations of those events under-predicted the entrainment, where when they ran the tests they got a lot of entrainment, actually got the level into the core. RELAP couldn't predict that. It was getting too high a level.

Now, those tests are not a good indicator of whether you will have core uncovery or not. But they are indicative of the fact that for flows similar to AP600, AP1000, you will have a lot of entrainment. One thing I want to point out, there's two different entrainment processes. We talked about this at the combined subcommittee meeting a couple of weeks ago and I want to make sure that we're clear on the distinction.

One is entrainment in the hot leg and we're looking over at this region of the figure where gas that leaves the core goes into the hot leg. The principal view that people have is that there's a stratified level in the hot leg. The high gas velocities entrained droplets from this stratified layer and it gets swept into the ADS. Where we did have some discussion and what I think a better view is called for is, where we really expect the most entrainment is when the levels are fairly high in the hot leg.

It's not quite entrainment from a stratified layer but what we've seen or I should say some of us have seen in -- of some flow visualizations that have been done at OSU is that you get entrainment there but you also get most of your entrainment from plugs intermittent flows that occur in the hot leg. Now, trying to predict that, trying to scale that leaves us at a loss. When we take the best correlation that we can find, best we can say at this point is we'd expect a lot more entrainment in AP1000 than what we would expect in the tests or in the AP600, but we can't put a good number on that.

MEMBER KRESS: In other words, it's kind of self-limiting as the level gets down --

MR. BAJOREK: It may well be. I think my point on this is this is something that we cannot say at this point has been well scaled in the tests but keep in mind, when it occurs, there's a lot of water in the system. This is up close to the top of the hot leg.

MEMBER KRESS: Yes, so one asks the question, does it really --

MR. BAJOREK: It is --

MEMBER KRESS: -- from the standpoint of safety?

MR. BAJOREK: My point here is, is the data acceptable to evaluate these models in the code? That's one question. Well, even if they aren't, then those models are not doing a great job, the other question that needs to be answered, I think, in Phase III is how safety significant is that? The answer that's still open, okay, and we have our opinions on that at this point is, well, is this really going to be important to the safety of the plant and uncovery of the core if you aren't predicting this properly.

My opinion is probably not, but we've got to get --

MEMBER KRESS: It's kind of a race. You've got the decay heat driving stuff off and if you -- and it's going down and if you've thrown out too much already, you're starting from lower level, it means you're going to dip farther into the core depending on how much that was.

MR. BAJOREK: Right, right. Now, this process goes away when you start to get down into the core and --

MEMBER KRESS: Does this -- does the fact that you now have a 14-foot core instead of a 12-foot one impact on this at all?

MR. BAJOREK: Not this because the upper plenum hardware has remained the same.

MEMBER KRESS: Oh, the same.

MR. BAJOREK: Unless I've missed it, Mike. Upper plenum elevations and that hardware is identical to the AP600.

MEMBER SIEBER: What's the distance from the top of the core to the bottom of the hot leg?

MR. BAJOREK: I estimate it as 1.82 meters based on some numbers that I had, six feet or so.

MEMBER SIEBER: Six feet.

MR. BAJOREK: Yeah, and that's to the top of the active part of the core. The core plate is a few inches off of that.

Now, I think what you were referring to, Dr. Kress, was the other entrainment process that starts to become dominant if you have scenarios that lead to a two-phase level that drops below the top of -- the bottom of the hot leg.

MEMBER KRESS: Yeah, that's what I was concerned about.

MR. BAJOREK: Now, this gets away from the slugging and stratified entrainment in the hot leg but it's a different physical process by which you have gas bubbling through a pot, in this case liquid trapped in the upper plenum, entrains these droplets and if that gas velocity is high enough, it sweeps those out through the ADS.

Now, where this starts to get our attention is in the double-ended guillotine break of the DVI line, where calculations done by both the staff and Westinghouse suggest that that level will drop and reach a minimum, I think it's about a foot above the core, more or less. Our question now is, if you do not predict that adequately, are you looking at a level that remained in the upper plenum or potentially drops into and uncovers the top part of the core?

So we focused more of our attention on scaling this process from a bottom up viewpoint. And on page 8, I put a little bit of that -- those numbers and some of the scaling criteria that we used to take a look at this process. First, this is something that does show up being highly ranked in the PIRT. Okay, this is Westinghouse's and what we also believe to be correct it this is a truly important process, especially for this double-ended guillotine break of the DVI line.

And as I mentioned just a few minutes ago, tests that were done after the AP600 program, did show what when you had the two-phase level below the bottom of the hot leg, I did have significant amounts of entrainment and that we had a very difficult time trying to determine how much should be entrained in a calculation using RELAP. Now, there's a flock of correlations that have been proposed to take a look at this. The chemical industry very interested in separations processes, so we see an amount of work.

Principally, what happens is it depends on one, what's the gas velocity as you bubble through this pool and secondly, how far to you have to entrain a droplet before it goes up and out of your system. So it's basically two parameters which are dominant in these correlations.

MEMBER KRESS: E is defined as the ratio of the mass of liquid to the mass of vapor?

MR. BAJOREK: Right. It's a mass of the liquid -- it's the liquid flux over the gas flux. Okay, and it's a dimensionalist way of representing the entrainment. Looking at the correlations that we find to be closest to the AP1000 in the test and we did find those to be in the same range, okay, we find that this relative entrainment scales to J_g the gas velocity to the third, maybe the fourth power.

MEMBER KRESS: That's looking at these correlations you say exist.

MR. BAJOREK: Yes.

MEMBER KRESS: I mean, it doesn't come out of this. It just --

MR. BAJOREK: These are correlations that were done. There was some work done in Russia to take a look at this. Ishii had done some work at Argonne. There had been some other work. They all basically suggest that E scales with J_g to the third, fourth or higher power.

So I defined a scaling ratio based on those correlations and if you assume, as I think we've just heard, AP600 has the same upper plenum hardware, same geometry but you increase the power by 75, 76 percent, you can very quickly estimate that the AP1000 should have at least five times the amount of entrainment that occurred in the AP600.

MEMBER KRESS: Now, this is decay heat driving this.

MR. BAJOREK: This is decay heat driving the --

MEMBER KRESS: So you wouldn't quite expect the same ratio of decay heat as due to the power, would you?

MR. BAJOREK: Well, no, we did take that into account. Yes.

MEMBER KRESS: Oh, the 75 is --

MR. BAJOREK: Yeah, the decay heat goes up by 75 percent.

MEMBER KRESS: Okay.

MR. BAJOREK: So the power -- depending on when you look in the transient, that's scaled power still goes up by 75 percent. Now, there are some differences in pressure and in what that scale power was in the facility and we sharpened our pencil and we looked at those and we found that SPES or AP1000 would have over 100 times the amount of entrainment as the SPES facility, roughly 20 times what you saw in ROSA facility.

APEX, only about six, somewhere between -- well, I estimated 6.3. APEX is a lot closer. It still is a bit of a concern because the way APEX got closer was not because of the gas velocity being correct for the entrainment but the fact that it was a one-quarter facility. So we're looking at it in -- from the viewpoint that APEX is closest at this point. It's distorted in a non-conservative direction but the one-quarter height may actually save some of those test results so that eventually they may be able to be applied to the AP1000.

But our conclusion to date is looking at this process, which was ranked high by Westinghouse, using the best information we have, we find that none of these test facilities were appropriately scaled to capture this phenomena which we think is going to be important in determining whether we have uncovery or not in the AP1000. So by conclusion --

MEMBER KRESS: So your concern, though, is only on this upper plenum entrainment --

MR. BAJOREK: That's basically --

MEMBER KRESS: -- and not at the ADS-4.

MR. BAJOREK: We think we still need to take a look at entrainment in the hot leg. The question is, well, how does this effect other parts of the transient and you may want to use those results to make other decisions, not just on whether you have core uncovery or not.

MEMBER KRESS: So there's two areas of entrainment, the ADS-4 and then the other one is --

MR. BAJOREK: The other is the hot leg. In one case, I think it's a lot easier to make the argument it may not be safety significant. And I think that's the distinction. So by conclusion, we should lost sight of the fact that by and large those tests for AP600 are still valuable. They cover -- they answer an awful lot of questions for the AP1000.

We feel there are a couple of issues, a couple of problems that stand out as exceptions to that. Both involve entrainment. As we looked at the RAIs, information that was submitted to Westinghouse and results of our own independent investigation, at this point we conclude that Westinghouse has not demonstrated that the test data is adequate for validation for these processes and we suggest that they and we need to come up with either alternative data, a different criteria for scaling or some new test results in order to close out these issues and we think this is going to be something that we need to look at in Phase III.

MEMBER SIEBER: Has that decision been made yet, which of the three approaches?

MR. BAJOREK: No, we've -- in the SECY, I believe the language is such we're leaving this open for discussion. We're not saying you've got to go out and run tests because there may be other entrainment tests that can be used. They may not just be what was done in the original AP600 test.

MEMBER SIEBER: But of all the phases, this is the most important because it results in the loss of inventory.

MR. BAJOREK: Yes, this one is going to basically show us do you have core uncovery and some clad heat-up or not in the AP1000. Now, again, I think there's -- you can do some other work looking at how quickly you should lose liquid from the upper plenum. Again, you may be able to demonstrate that the uncovery that you expect is not going to be significant or that it's going to take so long to get that last bit of liquid out of the upper plenum, again, your concern may not be justified.

But at this point, the data doesn't bound the types of things that we expect in the AP1000.

MEMBER KRESS: If more data were needed,

can APEX be used to produce that data?

MR. BAJOREK: I think so. In fact, I think that a series of tests could be run in the APEX you should do something to the no reserve but you do it under steady state. Okay, they still had complications in the no reserve because they started from a high pressure and flashed a lot of liquid. Run some steady state tests to get the effluent and the exhaust flow rate and bench mark these correlations which we still have questions about. I mean, these --

MEMBER KRESS: What would you do about the H difference?

MR. BAJOREK: The H difference, I think, can be addressed, although I would not do that in the APEX facility itself. There is a sister facility out at OSU called ATLAS. It has the same diameter vessel.

MEMBER KRESS: ATLAS. That's the one we saw.

MR. BAJOREK: That's the one we saw but they didn't have anything in their upper plenum, okay, or above the core. But they do have some nice visualizations and working with plexiglass and lower pressure is a lot easier than messing around with APEX, where you have all the instrumentation. I think it would be very feasible to put in upper core plate, simulated upper internals, a couple of DP cells and try to get at some of these same things. There you could, I think, fairly easily change your upper plenum geometry, okay.

You could put in what I'd call a donut in the upper plenum to restrict some of the flow and change your gas velocities or change the height of the core plate and get at some of those things. So an answer, yeah, I think APEX would help. I think maybe that sister facility may be a better place of exercising some of these parameters that apparently effect the correlations.

MEMBER SIEBER: Just stepping back and get the big pictures. ADS operates to get the pressure down enough so that you can inject from the accumulators. Roughly, what is that period of time from the time that ADS-4 begins to operate until the accumulators inject and I'm sure it's a function of break size.

MR. BAJOREK: Yeah, it's -- I believe that what happens in like a double headed guillotine transient is that the accumulators come in while you're still depressurizing. The length of time then between ADS -- or excuse me, accumulator injection and the time you actually get the IRWST is on the order of several hundred seconds. Mike, do you remember that?

MR. CORLETTI: Yeah, the core makeup takes time to drain in about 20 minutes and then after that, the ADS-4 is actuated and IRWST injection can occur immediately to some time there's a delay a hundred, couple hundred seconds. It ranges, as I said, based on the break size. But it's not a long duration and essentially once you get the IRWST injection, we're flooding in the vessel in the hot leg and so we're up to, you know, a lot of water, a lot of water in the system.

MEMBER SIEBER: Now, once ADS-4 operates, it's there forever, right? It's open.

MR. CORLETTI: It's open, yes.

MEMBER SIEBER: Open to the containment forever. All right, okay.

MR. CUMMINS: This is Ed Cummins. There is actually a black valve that you could close but that's not the intention. The intention is that the steady state safety case remains open.

MEMBER SIEBER: Right.

MEMBER KRESS: But even then, steam condenses on the walls and goes back to the IRWST.

MEMBER SIEBER: Yeah, there's a reciro path that -- yeah.

MR. BAJOREK: Okay, well, thank you and I think the next presentation is by Ed Throm and he's going to talk about the containment issues.

MR. BURKHART: This is Larry Burkhart just to be clear, our assessment on the codes testing and exemptions issues we documented in a letter to Westinghouse, not in a SECY.

MR. THROM: Good morning, my name is Edward Throm and I'm with the Plant Systems Branch and I'll be going over the WGOTHIC computer program review that was done for the AP1000 Phase II evaluation. WGOTHIC is the computer program that Westinghouse uses to evaluate the design basis accident response of the containment to double-ended guillotine primary LOCAs and main steam line breaks.

The code is described in WCAP 14.407 and basically WGOTHIC is an extension of the numerical applications incorporated GOTHIC 4.0 computer program and what Westinghouse did was included a model in the code called a Clime which represents the heat transfer modeling to look at the condensation on the inside surface, through the wall and the evaporation of the PCS water flowing down the outside of the vessel.

The staff's evaluation was presented in NUREG-1512. It covered the scaling studies, the part studies, the testing program, a description of those parts of GOTHIC that we reviewed, our review of the Clime model and our overall conclusions on the acceptability of what we came to call an evaluation model for doing these types of analysis.

The evaluation model basically consists of the use of the lumped parameter modalization process in the WGOTHIC program. We believe that the lumped parameter approach is applicable based on looking at the buoyancy of the jets Froude number scaling, also in looking at international test programs such as the Patel model containment and the HDR which showed that you would get a fairly well-mixed environment for all parts of the transient.

One issue that we had to deal with was the large scale test facility. It was not really scaled for transient applications, so there were a lot of questions on the circulation, stratification and mixing of the steam environment within the containment.

Westinghouse has addressed these in conservative manners. Two address circulation, for example, after the blow-down period, they don't take any credit for steam that might get into the dead-ended compartments below the deck. So they're not trying to take any credit for any mixing that the code might be calculating because of the uncertainties. Stratification is also a concern with potentially creating an air blanket on the operating deck which will be a relatively large heat structure, so they don't take any credit for the operating deck as a heat structure in the analysis.

Also for horizontal surfaces that may get condensing pools on them, they also don't count those as heat structures. The other things that are done in the evaluation model, is the PCS flow and mass and heat transfer models are conservatively used. They use minimum PCS flows in the massive heat transfer models. They apply multipliers onto essentially bound the uncertainty in all the data that went into developing these models.

The AP1000 is a little bit different than the AP600 as been noted before. The power level is quite a bit higher, about 75 percent. The vessel itself is about 25 feet higher. It's a slightly larger volume. In looking at the PIRT and looking at the fact that the AP1000 is using the same mechanism for heat removal, we didn't see any changes in the PIRT rankings of the important phenomena. There were a couple of issues that we were concerned with in going up to the AP1000.

One of them was whether or not the shell temperature would get above 212 degrees Fahrenheit before the PCS water came on. If that were to occur, then we would have a problem with the model for the film. We'd have to consider boiling of the film and potentially breakup of the film. Westinghouse did calculations that showed that at the time the PCS water would be credited in the calculation. The shell is only going to be about 180 degrees, so we don't have to be concerned with that particular problem.

The other one was in looking at the increased power and basically size of the AP1000 and the stored energy and mass is somewhat larger than the AP600. So the question was, are the massive heat transfer correlations still being used within their applicable range. And that was pretty much the focus of the review was to go out and look at the mass and energy, the heat fluxes that had to be addressed in the correlations.

Okay, then in summary, no new phenomena were identified in the process and the PIRT rankings remained unchanged. The heat transfer models and correlations are being used within their applicable range. This is based on scoping studies that

Westinghouse performed provided to the staff in December of last year in which they looked at most of the dimensionalist groups and found that the expected performance of the AP1000 wold fall within the applicable ranges of all the data upon which these correlations were based.

So we basically feel that WGOTHIC when used with the evaluation model, is applicable to the AP1000. The lumped parameter, mixing, we expect it to be a well-mixed environment. They're still using the same conservative approaches in addressing circulation stratification and heat transfer. In Phase III there are some things that we need to go back and look at because the scoping analysis were not done completely in accordance with the evaluation model but they're very close.

They have not applied what they call their evaporated flow model. And this is just a model that adjusts the PCS flow to only take credit for the amount of water that you could evaporate. The standard review plan has mechanisms or guidelines for calculating the mass and energies from both LOCA and steam line releases. The LOCA analysis that was in the scoping analysis is not quite in conformance with what we expect to see in the design certification analysis but we don't believe that that's a problem. Also in the scoping analysis that Westinghouse did, they looked at the ADS-4, IRWST and sump flows based on the AP600. There's going to be some changes to those in the long term and defining the mass and energies that you have to account for in the process.

So during Phase III we will go back and look at those evaluations again and we will -- Westinghouse, I believe, is committed to providing us with similar evaluations to demonstrate that the codes are still being applied within the applicable ranges.

I don't see any particular problem with the expected changes in those but we reserve the right to assure ourselves that we haven't gone outside the applicability of the code. We have done Contain 2.0 audit calculations for the scoping analysis. We got a very good comparison for the steam line break where the passive containment cooling system is not really a contributor to the peak pressure calculation.

We did do the large break LOCA calculation. We did not do it for a licensing case but we did it for the one of the reference cases that Westinghouse provided us back in December 2000 we calculated a peak pressure of about 54 psia compared to that calculation which would have calculated about

60 psia. The contained two code is designed to be a best estimate code for all practical purposes.

We did to a sensitivity study that tried to mimic the penalties or multipliers that Westinghouse applies to the heat transfer correlations and we got about a two psi increase which we would expect. We've not yet attempted to model or remove any of the other heat structures from the contained code to see if we could actually predict all of the conservative features that are in the evaluation model that Westinghouse uses with WGOTHIC. We do plan to perform audit calculations as part of the Phase III review once the mass and energies are finalized and Westinghouse provides us with the detailed information to make sure we've got all the volumes and heat structures that we do apply in the code properly marked.

So we believe that the WGOTHIC code is applicable to the AP1000. That it will be used within its range of applicability in terms of the mass and heat transfer models that Westinghouse developed for the PCS. That's all I really wanted to say this morning.

MR. BURKHART: Great. Now, we'll turn it over to Walt Jensen to discuss the applicability of the reactor codes.

MR. THROM: Thank you.

CHAIRMAN APOSTOLAKIS: No, if he wants to stand, he can stand. Do you want the mobile microphone?

MR. JENSEN: I'm Walt Jensen of the Reactor Systems Branch of NRR and I was responsible for the review of the LOFTRAN, NOTRUMP codes that will be used by Westinghouse for analysis of AP1000. The LOFTRAN code is used by Westinghouse for non-LOCA transients, including steam generator tube rupture and it's used with other codes to assess the maximum reactor system pressure, fuel temperature and the DNBR that might be obtained.

The NOTRUMP code is used for small break LOCA but in the time between a break occurs and stable flow is established from the IRWST. After that the WCOBRA track code is used for long term cooling evaluation. And the staff did detailed reviews of both these codes for operating plants in the mid-1980's and again for AP600 and wrote an SER in 1998.

The review process that we took just these codes that have already been reviewed in some detail in the past. We looked at the differences that might effect the analysis between the AP600 and the AP1000 plants. In particular the PRHR heat exchanger carries a greater heat exchanger carries a greater heat load. Steam generators are larger and the ADS-4 is larger and carries more flow and has a greater role in small break LOCA mitigation than it did for AP600.

We looked at the scaling, which you've just heard about, of the tests that were used to qualify the codes for AP600 to see if they would still be qualified for AP1000. We obtained the Westinghouse standards for generating input to the codes and this is important because both codes are very versatile and allow many user options. And Westinghouse has established the set of options that should be used to analyze the passive plants and we reviewed those.

And then we performed independent audit calculations using RELAP5. We looked at a main steam line break, small break LOCA. We got similar results as Westinghouse for small break LOCA, but we did get a very minimal amount of core uncovery for the double-ended DVI injection line break. We took a look at the limits in NOTRUMP and analyzing the PRHR heat exchanger and we looked at the hot leg velocity and how it might effect the entrainment going out of ADS-4.

First, conclusions with LOFTRAN, we found

LOFTRAN was capable of analyzing the anticipated transients and accidents, non-LOCA, for AP1000. However, the steam line break is still open. Westinghouse has not performed the steam line break for AP1000 and we are concerned that the voiding in the reactor system might extend beyond the capability of the LOFTRAN code, though they have done one preliminary calculation of steam line break that shows there to be very low voiding.

The NOTRUMP code, we also found that to be acceptable with the following exceptions that are still open, and number one is the liquid entrainment out of the -- which began in the core into the upper plenum and out of ADS-4. Westinghouse has proposed to bench mark the NOTRUMP code which has a very rudimentary entrainment model against the WCOBRA tract that they've modified with correlations to predict entrainment and then they will bench mark that WCOBRA tract code against experimental data which is still under discussion with the staff.

Perhaps we will do some sensitivity studies with RELAP to see the effect of entrainment on the core. The conservatism of the PRHR heat exchanger model is still under review. There's a limitation in NOTRUMP to limit the code to flow rates in the primary side of the PRHR heat exchangers to less than 1.5 feet per second and this is based on a limit in the heat flux comparisons with the experimental data by the time correlations that's used in NOTRUMP that was found to be non-conservative in comparison to the experimental data for high heat flows.

So we'll be looking at that but preliminary studies here show that the PRHR heat exchanger flow has a very small effect on the course of a small LOCA. And finally, we only looked at a few breaks with either RELAP or NOTRUMP and the entrainment issue is still open and this will effect the results. So if core uncovery is calculated, we will have to take up the review of the core uncovery models in NOTRUMP and in the SBLOCTA code that's used to evaluate the final core temperature when the core is uncovered.

So that's where we stand at the end of Phase II and we will be continuing the review in Phase III. Thank you.

MR. BURKHART: Thanks, Walt. Just a quick summary, again, the scope of Phase II was limited to four issues. You've seen this slide before, this was from my introductory slides. As you've heard in general, the AP600 testing program and analysis codes are applicable to the AP1000 design. We've noted some exceptions and where we will focus our efforts on the review during the design certification review.

We've also shared that the staff finds the DAC approach in the I & C, human factors, control room design and piping areas acceptable and also that the three exemptions that are proposed for AP1000 are applicable. And that concludes our presentation of the staff's assessment. I'll turn it over to Mike for Westinghouse's presentation.

MR. CORLETTI: We'll have Bill Brown, will be our next presenter, will be presenting some of the issues in regards to the applicability of the tests in response to Steve Bajorek's presentation.

MR. BROWN: Okay. PIRT scaling and entrainments assessment; Steve's already covered a lot of this which we pretty much agree on most points, and that is that there is no new phenomena expected for AP1000 and we've already submitted our scaling analysis to demonstrate that our 5600 test facilities are applicable to AP1000. We previously presented this work to both the NRC and the ACRS subcommittee.

Obviously, there were some issues discussed here with respect to entrainment, especially in the upper plenum and because of that, we went back and did some additional evaluation and some scaling which I'll present here in a moment. Before I do that, though, I thought it was maybe a little bit helpful in that I tried to come up with a -- sort of an integral effect type of a slide to put this entrainment a little bit in a system level perspective. I know we kind of have focused on this a lot from a very separate effect level and it certainly is something that is considered to be high ranked or important during the ADS to IRWST transition phase of the transient but I think we need to keep in mind a couple of things that are going out during this time frame as well as not only do we have stuff going out but we've also got potentially a lot of stuff going in.

And one of the biggest things to always keep in mind is that we've got roughly a 600,000 gallon tank sitting up here after the core make-up tank, which is continuing to drain through the ADS-4 as well, that is certainly willing to sit there and feed whatever entrainment that might be going along, but based on our testing and a lot of the analysis that we had done on the AP600, what we would expect to see here which we had seen in AP600, is more of a situation where you might start off in a phase where you've got the ADS-4 is on and been actuated and is in here venting steam to reduce the RCS pressure.

We've got injection from a core makeup tank and then later here with a significant amount of water from the IRWST potentially available here to inject. We've got liquid perhaps in a first phase being entrained from the upper plenum due to the high steam flow associated with the AP1000. We would expect some amount of phase separation in the hot legs.

Some of the de-entrained liquid here would initially start to accumulate somewhat in the hot leg. We would expect that this process would continue. As Steve mentioned earlier, we probably wouldn't initially get a significant amount of entrainment through the ADS-4 at this point until we reach a critical inception level within the tanks so that the velocity is high enough and to draw it, sort of a Bernoulli effect, sort of sucking the water out of the hot leg, so that we continue replenishment here in the IRWST.

The ADS-4 would still be venting and eventually we hit this point where we begin to hit an inception point we now begin to entrain the liquid up into the vents. At that point, then, as we would draw the liquid up into the vents at this point, now you've got the vents now that were predominately venting steam out probably got to clear this liquid out, so at that rate we'd probably see a bit of a reduction in the amount of injection but on the other hand, now you don't have a nice path for the steam to go out any more, so now you've temporarily got a lower velocity of steam and so you've got an entrainments reducing.

So the system is kind of correcting itself here a bit and it's clearing itself purging the liquid out. So eventually you clear out, so again you get the pressure back down, you've vented the steam here, so now you can resume to inject more water and entrain more liquid out here and the process would then repeat and we would see this going on through the long-term cooling phase.

So that just sort of sets up a little bit of the, I think, more of a system level effect to put the local entrainment into context for you.

MEMBER SIEBER: If I look at the slide 9 and compare it to your drawing, it looks like ADS-4 comes off the line at the next ER of EST to the hot leg, instead of as you show it there where it comes in.

MR. BROWN: The ADS-4 here?

MEMBER SIEBER: Yeah.

MR. BROWN: The ADS-4 comes off the top of the hot leg.

MEMBER SIEBER: Now, the IRWST line comes in the same place, right?

MR. CUMMINS: This is Ed Cummins. I think the thing that you're looking at is the PRHR heat exchanger.

MEMBER SIEBER: Okay.

MR. CUMMINS: The PRHR heat exchanger is a tank within the IRWST. It is connected to one of those two ADS four lines.

MR. BROWN: Off the top of this line right here, you would have a connection from PRHR off of one of these ADS-4s that continues up and then that comes up into here which is the exchanger sitting in the tank here.

MEMBER SIEBER: All right.

MR. CUMMINS: If you look at slide 10, in your presentation, all the injection from the core makeup tanks to the accumulators and the IRWST for make up to the reactor vessel, is through two direct vessel injection lines which are basically independent of other lines.

MEMBER SIEBER: Okay, I see that. Thank

you.

MR. BROWN: In fact, we finally see in the tests that the PRHR actually helps to provide fissional depressurization because it does condense more steam.

MEMBER POWERS: Can you give me a feeling for during this period where you have entrainment what the superficial gas velocity through the core region is?

MR. BROWN: Through the core region itself? Well, obviously not as -- I think really the highest velocity you could get is through the upper core plate. That's really the highest velocity that you get. It's pretty substantial. I'm trying to remember what that was off-hand. Steve, do you remember? Is it 100 feet a second or something like that? I think it's pretty high. And it's moving up through there, yeah, yeah, to the core plate and then you would expand into the upper plenum where you --

MR. BAJOREK: This is Steve Bajorek for Research. I don't exactly remember the velocity at the core plate. However, in the AP1000 your superficial velocity through the upper plenum, the free part was about two and a half meters per second. So given that there was a restriction down at the core plate, three to four maybe.

MR. BROWN: It's probably somewhere between those to if you want to try to bound that, yeah. It's definitely higher than AP600.

Well, I just wanted to start with that one, just to sort of put it in sort of a system level context, so Steve's gone over some of this before. We've looked at the -- first of all in the upper plenum entrainment. Some of the work by Katoaka-Ishii looked at full entrainment in vessels and identified a near surface region and a momentum controlled region.

The near surface region, very, very close to the water surface, was found to correlate simply on a density ratio. The momentum controlled region, where you would move further away from the surface of the liquid, was found to be a function of density ratio, hydraulic diameter, viscosity number, but primarily most strongly upon superficial gas velocity divided by a dimensionless height. So it's really a combination of the two of the J_g star and an H star which are really the dominant terms in the momentum controlled regime.

And to help you a little bit we're trying to put this again, in context in terms of what type of events might this be of interest to us or what type of events would we be looking at things where we have, for example, a level in the hot leg, we would be more interested in what is the near surface type of entrainment where we essentially have water already in the hot leg, we're not having to lift it up from the vessel into the hot leg, it's already there, versus events where we would get into a momentum controlled regime where we've got to actually lift the water droplet up into the hot leg.

If you think of some of the two slides that Steve just presented, you can see a good -- he had a better picture of that than I do. These would give you an idea of the type of events that we've seen not just from analysis but also from looking back at the OSU tests for example, and all the test programs. Typically, the half inch, the one inch, the two inch cold leg breaks, the hot leg break, two inch DVI and the doubled ended core make-up balance line break, all typically have a level within the hot leg already. So for those events we've got a level in the hot leg. We're in this near surface entrainment regime and looking at the scaling. This indicates that we're simply a function of a density ratio and since we essentially have pressure scale facilities, the scaling is good.

So the one in which we have a momentum controlled regime where we don't have a level in the hot leg, really is the DE DVI line break. So this is really the focus of all this. So we even talk about entrainment, you know, trying to put it in a system level context and now in terms of events, which ones are we focused in on. So we really, if you look at all these tests, we're well scaled as far as entrainment is concerned.

In the hot leg, for example, we've got mixture levels in there and it's really only the DE DVI line break that we really need to focus in on. So based upon looking at this type of pool entrainment, similar to the work of Kataoka-Ishii, we would say that the entrainment is well scaled in the test facilities for small break LOCAs where we've got a mixture level in the hot leg, which was most of the small break LOCA events I just listed, where pressure is preserved and therefore, density.

It's in this momentum entrainment, momentum controlled regime in which we're dependent upon the superficial gas velocity divided by height in which we have a potential distortion in the AP600 test facilities due to the fact that we do have a higher superficial gas velocity in the AP1000 core.

MEMBER RANSOM: Excuse me, what is the dimensionless height? Is that just a height through the outlook flow?

MR. BROWN: Yes, it's basically, if you did a measurement, yeah, it's basically how far do you have to lift up a droplet in order to carry it away, right.

MEMBER KRESS: How do you non-dimensionalize it?

MR. BROWN: It's non-dimensionalized, I think, it's got a square root of density difference, gravity and surface tension. I think that's how it's -- so essentially, again, if you have a pressure scale facility, you're just looking at just dimensional H really and the velocity. And we are at this time in the transient, we've essentially depressurized in the facilities. We're to the point where you're really looking at just J_g divided by H, dimensional.

It gives you a little better idea, I guess on the next page here. I tried to put this together a little bit in another way to digest this correlation. Some of the details are down below, but essentially if you were to start off with the correlation here that Steve presented earlier, that you've got the J_g divided by H star cubed and the viscosity number and the hydraulic diameter number, you can eventually -- you can relate this for pressure similitude and for saturated conditions in the vessel. You can come up with an expression for J_g and come up with a simple expression like this where you've got core power, area, height, and the hydraulic diameter ratio here as far as looking at entrainment in a pool type situation. So this is really the basis for which to look at.

And the key is, is obviously, this term right here is really the -- obviously, the dominant term, the core power and the height and the area. When you try to take this scaling ratio and put some numbers into it, similar to the question you asked Dr. Powers about the velocity and so on, if you sort of range the velocity through the upper core plate up into the upper plenum, you would come up with a number in this range of roughly a quarter to a half, which, you know, based on our criteria, the half were here, based on the criteria that was used previously by Brookhaven for AP600, at roughly a third, it kind of looks like we're -- you know, we're kind of close.

So you know, we find that we're certainly in the range at which I think Westinghouse would say that, well, there may be a possible distortion, we're certainly on the non-conservative side, as Steve says, but we don't think that this distortion is very far off that we can't use this data for code validation purposes for AP1000.

The next step, I sort of tried to ask myself a little bit presented before to the subcommittee was, well, what does this -- what might this correlation look like? If I were to come up with a little simple model of an upper plenum mode where I had really no water in the hot leg and I was just worried about I've got some mixture level sitting up above the core in the upper plenum at the bottom of the hot leg and what if I put in this pool entrainment correlation and essentially assume that the core decay heat was driving it off. I had just enough liquid here or mass flow to make up and match decay heat at that time. Well, what might happen and how long might it take for this entrained liquid to effect the upper plenum level?

So I come up with sort of a simple little model here in which I had a transient conservation of mass here for the upper plenum and I just started with the upper core plate to the bottom of the hot leg as this initial two-phase region. And I used a simple void fraction correlation using the YEH correlation here to determine void fraction in this area right here. And then I used the upper -- for the upper plenum entrainment, then I used the pool entrainment correlation form from Kataoka-Ishii here to try to determine what was the mass flux of the liquid that was entrained out of this mass and then from a conservation of mass on the core, and I just for conservatism I decided not to even account for any of the sub-cooling which might help me here and said, well, even if I just simply have saturated conditions in the core here, what might my steam generation rate, steam velocity be?

So then I did this, and I put this into MathCAD. This is the result I got which showed that very, very quickly, extremely quickly, I approached sort of a quasi-steady state level above the top of the core plate here and within seconds, I reached an equilibrium level. So, very, very quickly this very strong function of entrainment, this J_g really dropped me very rapidly but then, of course, remember that it's J_g over H and so H very quickly restores you into sort of a self-limiting type process and so at some point you very rapidly settle out at a steady state level.

So it kind of gives you a feeling of what the -- how the correlation and the behavior should be for this type of entrainment. So what I concluded from this was that are entrainment was sufficiently scaled in the upper plenum for all possible events with the exception of maybe the DE DVI line break in which we didn't have a hot leg -- a level up in the hot leg for very long there during this phase. And that the entrainment scaling was really of concern during this transition phase of the DE DVI vent where we were subject potentially to this momentum controlled regime. That this distortion in OSU does not appear to be so large that would render our codes unusable and that the momentum controlled regime, the entrainment in the upper plenum here seems to be somewhat of a self-limiting process because we've got the J_g relative to H and because of this, we don't expect to really see that there's going to be a serious safety issue here with AP1000.

We also looked at hot leg entrainment as well, and we expect to see a stratified type pattern, although certainly Steve says we may see some slugs in there and that's possible. I don't expect to see cliescent (phonetic) stratified flow but we certainly expect to see something that's stratified.

There's a Froude number type correlation with a length to diameter of up-take type of correlation which is responsible for predicting the onset of entrainment from the flow into the hot leg, into the ADS-4 and this was used to scale this.

The results of the scaling indicated that our Froude number seemed to be acceptably scaled to AP600 and AP1000. The real difference was in the dimensionalist ratio of liquid level in the hot leg relative to the ADS-4 pipe, which would indicate, which I would agree with Steve, we would expect to see -- we would expect to see entrainment begin at a lower level in the hot leg in AP1000 relative to AP600 and OSU.

However, I guess I'd say on the other hand, the fact that we've got a level in the hot leg and we're looking at those type of events, it's not something I think that's quite as much of a concern. We probably would accumulate less water in the hot legs, however, usually having the hot water -- having the level in the hot leg would tend to indicate we've got core coverage. So we're certainly not as concerned about that event than we would where we're going to go below the hot leg potentially in events such as a DE DVI event.

So some of our plans for trying to address this situation in Phase III, we're going to demonstrate through calculation and analysis that the entrainment phenomenon in the upper plenum and hot leg during this limiting small break LOCA does not challenge the safety and see it as sort of using a term of extreme entrainment here would be addressed on one of several ways; assessing margins relative to the regulatory limits, adjusting upper plenum/hot leg correlations to increase entrainment, assessing upper plenum de-entrainment due to the reactor vessel internals, also potentially increasing pressure drop in the ADS vents such as whenever the liquid is being discharged through there and we plan to submit a topical report to address this later this year in June.

The overall conclusions that I have from the testing and scaling, again, no new phenomena in AP1000. The separate effects and integral effects tests are acceptably scaled. Upper plenum entrainment, there's a local effect that appears to be self-limiting. We don't think additional testing is required.

MEMBER POWERS: Can I ask a question?

MR. BROWN: Yes.

MEMBER POWERS: Which you showed was a simple calculation --

MR. BROWN: Yes.

MEMBER POWERS: -- in which you had an entrainment and then you had water feed.

MR. BROWN: Uh-huh.

MEMBER POWERS: And you said, gee, it starts at one level and it comes to another level.

MR. BROWN: Right.

MEMBER POWERS: It seems to me that that's an unremarkable conclusion for a first order differential equation with a source and a think term to come to another level. That has nothing to do with the entrainment correlation. It has to do with the fact that you've got a loss term and a gain term. They balance each other if you go out long enough in time.

MR. BROWN: That's true, but I think I'm just trying to demonstrate the fact that I think sometimes when the entrainment is presented, people tend to forget about the fact that there is -- that in looking at certainly the relative order, that there certainly is a restoring term in there for H as far as how far that level is.

MEMBER POWERS: But that calculation

doesn't show that. I mean, the calculation only tells me a loss term and a gain term and the relative magnitudes of those two will determine where that balance is.

MR. BROWN: Yeah, and well, we're not trying to make -- at this point, not trying to make any claims about the absolute value of where that steady state level is. I'm not trying to make any claim about that at all. I mean, certainly this is a very simple calculation.

MEMBER POWERS: I thought what you were claiming that this was self-limiting because as that H got bigger and bigger it reduced that J over H term to --

MR. BROWN: Right.

MEMBER POWERS: -- the point that -- and that's just not obvious to me that that's the case at all.

MR. CUMMINS: Hello, this is Ed Cummins. I think what Bill did in his calculation just for simplicity, he set the in-flow equal to the out-flow so that the mass was -- the core was covered and what he was trying to assess was the effect of -- the separate effect of entrainment, which is the same thing that Steve was trying to assess. It's not the whole integral effect.

So if you assess the separate effect of entrainment, what is the effect of H and J_g working together for the entrainment phenomenon and I think those things suggest that at some level J_g dominates and then after awhile H corrects it.

MR. BROWN: The point is to try to find out at what H do we come to some kind of a steady state. I mean, I agree that it's a steady state calculation. I mean, eventually we're getting to that point, but there is an H associated with that J_g in which you balance and the question I have the interest is, is well is it something that looks like it's, you know, a foot or two away or is it 20 feet deep or how far into this thing does it look like it goes and so that was of some use.

MEMBER POWERS: I can make that carried out, just by changing your inlet term.

MR. BROWN: Well, it was driven by the decay heat in this case. I mean, the decay heat was driving the mass flow which was representative at this point in the transient. So yes, if I picked a different decay heat, sure I would get a different value and this certainly should decrease over time.

MR. CUMMINS: If you deal with -- Ed

Cummins again. If you deal with the entire system performance, then the top down scaling is appropriate and whether you get in-flow and out-flow depends mostly on the relative pressure drop between the forced states and the pressure available from the IRWST. But as we, I think pretty much agree with the staff, the top down scaling for the AP1000 is acceptable and we happen to be now looking at a bottom up scaling for a particular phenomena which is pool entrainment from the upper head pool and what we were trying to show that performance with some simple calculation to give you a feel for what the characteristics were.

MR. BROWN: I mean, it's very similar to some of the things we had done in AP600, looking in the containment. I mean, we all felt eventually that we would, for example, remove the energy through the containment shell. What the question is, is at what temperature would the inlet -- the flow through there balance and that's simply what I was trying to get at was, okay, given that this entrainment occurs, what would be the height at which I would reduce to given the core power which would, again, influence the velocity, at what height at which I would be able to balance the entrainment relative to the flow that was coming in? That's all I was trying to get at.

MEMBER POWERS: And again, let me control the source term and I can make that height anything you want.

MR. BROWN: Again, I would agree that if we put a different flow rate in there, we'll come to a new value. It's just that I was using typical values that we got from our safety analysis code at the time in which ADS-4 went off to represent to you what might that look like at the time when ADS goes off. And so we went into the code and said, okay, what's the decay heat during that period and said, okay, this is how many BTUs per second we're putting into this point, this is the energy that's driving this. What does that -- what might that steady state height come out to be?

Any other questions?

MR. CUMMINS: Yeah, I think it's important that we have not completed the calculation in the topical report we plan to submit. When you use the appropriate decay heat for the point of -- the point of time for the transient, I think, you're right, you could put any heat level in you want and drive any answer, but when you put the appropriate decay heat level, we'll have -- essentially we'll see a delta on what the level could be.

MR. BROWN: Yeah, and we were curious about that ourselves, so we decided to try it and see what it looked like.

MEMBER KRESS: Do you have this model built into your code?

MR. BROWN: Not this specific one like this, no, but again, this was again, sort of a --

MEMBER KRESS: I mean, the entrainment.

MR. BROWN: -- yeah, what would this look like if we were --

MR. CUMMINS: Ed Cummins again. I think when we deal with both injection and venting, we go back to the system level performance and we get away from the local effects. And if you remember I think both the staff and Westinghouse feel that on a system-wide basis, the AP1000 scaled well to the test and on a system-wide basis we would expect that the level predicted would be scaled.

MR. BROWN: Anyway we do intend to do a topical in which we would actually to certainly some more rigorous calculations here and so on. This was just in the time frame that we could get to present was to get some sort of an order of magnitude of what we were looking at relative to the best information we had as far as decay heat and so on at the time, the best estimate of a velocity we could get there.

Yes, Steve.

MR. BAJOREK: This is Steve Bajorek from Research. I guess I just want to kind of add to it. Our concern is a couple fold on this. As we look at things from a top down system-wide level, okay, we would agree that most things are okay. However, when we have to look at these bottom up processes, we have to limit ourselves to the steady state behavior and on that basis we are restricted because the correlations that are developed, we have questions on whether they apply strictly to the geometry that we're now trying to extend those two.

Secondly, when it goes back to the system-wide effects, we have to add flashing terms back into this. And when we look at both of those occurring simultaneously, this leads to our concern and question that even on a system-wide basis, should we be concerned with additional liquid being flushed out of this upper plenum.

So I think at this point we would still disagree with the statement that APEX is well-scaled for this particular process.

MEMBER KRESS: Okay, we have what --

MR. BROWN: Michael just has a --

MR. CORLETTI: Yeah, and I could probably summarize right from here. I think Bill's pretty much summarized our conclusions. Our conclusions with the tests in regard to the applicability of the tests remembering the four issues we were asking the staff to approve here was the applicability of our AP600 test to AP1000. We believe we've shown that by and large these tests are applicable and we believe are sufficient for certification for AP1000.

The one issue that does remain is this effect of entrainment. We believe we'll be able to demonstrate that when you take it in context with the large margins we have, and not only margin to core uncovery but also margin to regular limits as far as peak clad temperature are essentially -- for instance for one of the loss of core accidents for AP600 where we did have core uncovery that's for the 10-inch break, we had a core heat up of 400 degrees PCT because it was a very short duration.

We had -- essentially, this plant is not a small break LOCA limited plant and we will be able to show a very large margin to regulatory limits in that regard. So I think in that context, this is why we believe we'll be able to demonstrate that in our topical report with that sort of a bounding calculation.

With regards to our analysis codes, we are -- our conclusions were that they are largely applicable to -- they are applicable to AP1000 and then will be able to be used for design certification. There are certain conditions that the staff has pretty much made clear. They've spelled them out here and our plan is to follow those conditions as far as design certification.

In regards to the other issues on the piping DAC and I think we are in agreement with the staff's position on that.

MEMBER KRESS: Okay, thank you very much. I think that brings us to the end of this session. We're running a little late. At this time I'm going to declare a break until 11:00 o'clock and some of us will not come back, including our chairman.

MEMBER POWERS: And I won't be back here either.

MEMBER KRESS: So we won't have a quorum. so I guess we're recessing now till 1:00 o'clock.

MEMBER POWERS: And I don't think you need the Reporter any more, do you?

MEMBER KRESS: And I think this is the end of the need for a Reporter. We'll recess until 1:00 o'clock.

(Whereupon, at 10:44 a.m. the above-entitled matter was concluded.)

CERTIFICATE

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

Name of Proceeding: ACRS 490th 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.

John Mongovan
Official Reporter
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