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OFFICIAL TRANSCRIPT OF PROCEEDINGS

Agency: Nuclear Regulatory Commission
Advisory Committee on Reactor Safeguards

Title: Thermal Hydraulic Phenomena Subcommittee Meeting

Docket No.

LOCATION: Idaho Falls, Idaho

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UNITED STATES NUCLEAR REGULATORY COMMISSION

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

DATE: March 5, 1993

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UNITED STATES NUCLEAR REGULATORY COMMISSION

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

THERMAL HYDRAULIC PHENOMENA SUBCOMMITTEE MEETING

REVIEW OF RELAP5/MOD3 CODE ISSUES RELATED TO AP600 MODELING

West Bank Hotel
475 River Parkway
Idaho Falls, Idaho

Friday, March 5, 1993

PARTICIPANTS:

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ROBERT SEALE, ACRS Member
PETER DAVIS, ACRS Member
PAUL BOEHNERT, ACRS Member
THOMAS KRESS, ACRS Member
J. ERNEST WILKINS, ACRS Member
DAVID BASSETTE, NRC/RES
LOUIS SHOTKIN, NRC/RES
TOM KING, NRC/RES
BRIAN SHERON, NRC/RES
DON SOLBERG, NRC/RES
NORM LAUBEN, NRC/RES
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MARCOS ORTIS, EG&G
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RON BEELMAN, EG&G
GARY JOHNSEN, EG&G
S. MICHAEL MODRO, EG&G
REX SCHUMWAY, EG&G
CAL SLATER, EG&G
RICHARD WAGNER, EG&G

[continued next page]

ANTHONY BARATTA, Pennsylvania State University

VIRGIL SCHROCK, UC-Berkeley

V.J. DHIR, UCLA

DAVID A. WARD, Independent Contractor

NOVAK ZUBER, Independent Contractor

VICTOR BERTA

VINCENT MOUSSEAU

P R O C E E D I N G S

[7:32 a.m.]

MR. CATTON: Good morning.

We'll reconvene the Thermal Hydraulics Subcommittee meeting and start with section IV in the agenda, and the first person we'll hear from is Mr. Berta.

MR. BERTA: Good morning. I am Vic Berta. I'm with the RELAP5 staff in EG&G Idaho, and I will be presenting to you what we refer to as the second-tier items on the improvements to be made to RELAP5/MOD3. These items are listed here.

There is a method to the order I've got them listed. They are not exactly as they appear in the agenda. What I have done here is to organize them according to my impressions as to how much I have to say about them.

I have the least to say about the downcomer nodalization, and I have the most to say about the last item, the computation of the improvements for long transients. The others have kind of fit in there with that kind of a philosophy in mind.

First off, the downcomer nodalization -- the wording for this came down to us, as shown here under the improvement listing. It actually came to us in the terminology "downcomer condensation."

That was the essence of the problem, because the analysts were experiencing calculations that were giving atypical or unrealistic phenomena in the downcomer, which they had attributed to improper condensation.

At the time that they were doing those calculations and had come to that conclusion, the development or the stage at which the AP600 system model had been developed was fairly coarse in nodalization in the downcomer.

In other words, they had, essentially, fairly large volumes represented in there, and what was happening was that the cool liquid was coming into those volumes, the volumes were big enough so that instantaneous condensation was occurring with the steam that was also in those volumes, and that was giving problems on the calculation of the pressures and the flows.

MR. CATTON: What kind of pressures were you calculating?

MR. BERTA: That I'm not sure about. I think there were fairly wide swings, fairly rapid oscillations in pressure because of the rapid condensation that was occurring.

MR. CATTON: Could have been it was just a water hammer, a real one.

MR. BERTA: A real one, yes.

Anyway, subsequent to that time, they had undergone some further nodalization studies on that model, and they were able to arrive at a nodalization scheme such that these un-physical or atypical type of phenomena essentially went away and became realistic; if not perfectly accurate, at least it was realistic in the minds of the analysts.

What they have now is a downcomer that's divided into eight sectors, and each sector has a vertical stack of eight volumes. This, again, is based on 1-D philosophy for the code. They haven't looked at the usage of 3-D component, which we also have available in the code now.

Our conclusion, at this time, is that they should continue to investigate the nodalization of the downcomer and possibly extend that study to include the 3-D fluence component.

There is some work that's going on now in that area with other finite element codes to determine if there is 3-D type of behavior in there that should be modeled. If that proves out, then they should at least go into the 3-D component that's in RELAP5 and see if that helps out.

Now, if they do, then what that means is that that downcomer nodalization is going to become even more finely nodalized, and this gets into a condition that I refer to -- what we've seen over the years in several different analysis areas, and that is that the way the system is nodalized can lead to a calculation with a code that the -- is essentially not convergent.

By that, I mean that changing the nodalization, if we want to think about that, and increasing numbers of nodes for a problem, the calculation will change. In other words, you will get a new answer for each successive increase in nodalization.

Now, we've seen this several times in other areas, and this, indeed, may be one of those, and it was first manifested by the non-physical behavior that was seen there, and it's gone away from increased nodalization, and we may end up with a further increase in nodalization, which would, in my view, tend to make the solution to these transients more convergent.

Anyway, this task does not have any funding currently allocated towards it. If we see the need develop from the analysts in the future, we will take another look at it, but at this point, we don't see a need to go into the code itself to answer this particular question.

MR. WARD: When you say more nodes might make the answer more convergent, what does that mean?

MR. BERTA: I can give you an example.

MR. WARD: If you have too few nodes and you get a wildly, obviously inappropriate answer, you know you've got a problem, but if you have some nodes and you get an answer that isn't maybe wildly inappropriate but you still don't know whether it's right or not.

MR. BERTA: That's right. An example of that is a study that was done -- in fact, it's the only study that I'm aware of -- that was done on the LOFT core, nuclear core, with the hot channel in particular.

They did a study where they increased the number of nodes to represent that vertical hot channel in increments of one, and they got to six, and the answer continually changed as they went, of course, from very coarse, two or three volumes, up to six, but after six, the answer changed very little.

It did change some, but they thought, because of -- in those days -- this was about 10 years ago -- that the cost of running larger and larger nodalizations would become prohibitive, and they settled on six.

Well, subsequent to that, they did some experiments in LOFT, where we were able to match the results of the calculations with measured data in the core, and indeed, six looked like a very good answer as far as nodalization went.

Then, I was involved in another study where we tried to extend those results up to a full-size plant. We went to a 12-foot core and used the Zion PWR as an example, and after we had created a model of Zion in which the only difference was the height of the core, we used the same six stack of nodes in that core, and we expected to get the same answer, and we did not.

Not all of the information was there that was in the shorter six-node volume or nodalization for LOFT, and what that essentially meant was -- is we essentially did the same thing as if we reduced the LOFT nodalization from six down to three.

The LOFT core is only half the length of a full-size core. So, in that instance, we got away from a convergent solution.

If we had gone up to 12 nodes, we would have probably got the same answer again. So, that's what I mean by convergence.

You get to a point in the degree of nodalization such that you do not get a new answer.

MR. SCHROCK: Ivan, could I make a comment?

MR. CATTON: Yes.

MR. SCHROCK: I don't think that you can expect to get the right answer for this problem with the models that are in RELAP5 dealing with the interfacial heat and mass transfer. It depends too much on how much new surface is created as the two fluids interact.

When new surface is created, the condensation is massive for a short period of time while that new surface is being heated, and then the condensation rates drop off dramatically.

We did experiments on the injection of cold water into vertical tubes, and there is a paper in Nuclear Engineering and Design describing the results of that.

They are not applicable directly to the problem that you have because of the geometric differences, but the experience is sufficient to show that the massive changes in the condensation rate cannot be ignored if you're going to get this problem right.

So, you won't get that, in any way, out of the models that are in RELAP5 at the present time.

The mechanistic problem of deformation of the liquid, creation of new cold surfaces within the liquid is the heart of the problem, and you don't have the physics of that in the RELAP5 models.

MR. BERTA: That's true.

MR. CATTON: So, you almost have to go back and calculate the peak pressures.

MR. SCHROCK: I think you almost need an empirical approach, where you do a separate effects experiment, injecting water into that kind of geometry to see what the consequences are.

I don't see any other way, because you're not going to attempt to model what happens to the liquid as it's torn apart as it interacts with the vapor. I don't think you can do that.

MR. ZUBER: I have a question. You give several condensation levels in your code. Which one was used in these calculations?

MR. BERTA: I don't know. Do we have a user representative?

MR. JOHNSEN: Gary Johnsen, EG&G.

We're talking here about the interfacial condensation; in other words, the condensation of the vapor off the liquid, direct contact condensation.

MR. ZUBER: Okay.

MR. JOHNSEN: And the model that is used, depending upon flow regime that's predicted in the cells -- so, if it's bubbly, then there's a large interfacial area, and the condensation tends to be high.

On the other hand, if it were stratified, which in this case I'm sure it's not, the interfacial area is low, and the condensation is, accordingly, low.

So, it's dependent what the code predicts is the flow regime in the cells in the downcomer as to what the rate of condensation will be.

MR. ZUBER: You really don't know what the flow regimes there are, but what disturbs me is that you try to have physical and other questions in your modeling capability with an artificial nodalization, and I think this is the wrong approach.

I think, if you're going to spend my money, not government -- it's easy to spend government money, but this is not the appropriate model to do it. You cannot convince people that this is the right physics.

MR. BERTA: I wouldn't try to convince you that it's the right physics.

MR. ZUBER: If it's not the true physics, you have no confidence in the results.

MR. SHERON: Dr. Catton, I feel I need to respond to that, because quite honestly, if we followed that philosophy, we wouldn't be meeting here right now, because we would have nothing to present to you, because we would be off trying to develop a code that represented reality perfectly.

The fact is that we are trying to produce a calculational model that can be used by the agency to do a reasonable job of predicting the AP600 test plant in time for the certification.

If I followed the advice of -- I wouldn't do any calculations until I put in a perfect model that does everything -- that would be fine. Maybe in about 1999, I'd have a code that was capable of calculating this plant that would satisfy everybody.

The fact is we are trying to do the best we can. If there is a model that doesn't perhaps model the phenomena that is expected in this particular plant, decisions have to be made on whether we use approximations to get us through it, so that we can do the calculation.

We look at the results, we see if they seem a little non-physical, and maybe we can make some adjustments, but I cannot terminate the entire program in order to stop and go back and start from first principles to develop some whole new model to put in the code just because there is a new phenomena that the code doesn't happen to have a model for at that time.

MR. CATTON: I heard two suggestions. One said you ought to do something empirical, which seems to me is reasonable. I don't think anybody expects -- as a matter of fact, I think Professor Schrock said that it would be impossible for you to do it exactly, and that's correct.

MR. ZUBER: And I agree with that, and the point is go back to the experimental data we have and try to use experimental data rather than make a model.

MR. SHOTKIN: I have another suggestion. Brian says there is no funding for this. This came up as a result of a large-break LOCA calculation.

Well, you're not going to use RELAP5 for a large-break LOCA, and you're not going to put in models in RELAP5 to do a large-break LOCA. We're going to use TRAC.

MR. ZUBER: TRAC? Okay.

MR. CATTON: TRAC has its own problems with condensation. They all have the same problem, and it's the one that Virgil mentioned.

MR. SHOTKIN: Yes, but we aren't going to go through another large-break LOCA CSAU-type study for RELAP5.

MR. CATTON: Nobody is asking you to.

Why don't you continue?

MR. BERTA: The next area is the ADS and sparger condensation, and the wording for this improvement was to provide the ability to calculate condensation from flow through the ADS valves and SBWR safety relief valves through the spargers in the IRWST and suppression cooling.

This was one that I am also of the opinion that it is possible to provide a reasonable answer with a nodalization study, because what we're hearing from the analysts is that the code is calculating condensation and at least plausible representations, if not exactly correctly.

The same thing is happening there as what was happening in the downcomers, that the large volumes that are used for the nodalization is providing complete condensation.

So, what you're calculating there is really dependent upon the degree of nodalization again, and at this point in time, we do not know what that optimum nodalization is.

If we find that we have to go into the code and put in some new models or correlations into the code, what we would do is the standard way that we do the things, is that we would look -- seek out and find the candidate models or correlations, and then what we would do following that is to actually put those into a test version of RELAP5, develop the models there, and then once we have reached a state where we would accept one or more of those models, we would carry them into the mainstream RELAP5.

MR. CATTON: What are you look for as an output? Somehow I missed something.

MR. BERTA: I think we would want to have --

MR. CATTON: Are you going to model the safety relief valves, for example, and then have spargers?

MR. BERTA: Spargers downstream.

MR. CATTON: Where is the modeling difficulty? Is it in the pool outside of the sparger?

MR. BERTA: There is a problem there. Right now, at least up to this time, we haven't had any design information on either the flow characteristics of these valves or on the design of the spargers.

That information is starting to come in now. So, we'll at least have an idea of what that looks like.

We have also got a lot of experience, at least here, in LOFT, where we actually used a suppression system similar to the MARK 4 system on some of the full-size plants, and we have a lot of data there that says that we can get complete condensation for essentially very high injection rates of steam and two-phase mixtures into water pools.

MR. CATTON: There's the entire MARK 1, MARK 2, MARK 3 programs --

MR. BERTA: Yes.

MR. CATTON: -- where there's information available, and the spargers are very effective.

MR. BERTA: Spargers are very effective, but the question I have in my mind is I want to see what these designs look like first, because we may have a non-problem here.

We may get, for those injection rates, when we go into those, is the IRWST and the suppression pool. It may be such that we would get complete condensation for even the most -- for even the large-break situation.

If that's the case, then what the code is doing now is, in my opinion, all right. We don't have to go into the code and add these models.

MR. CATTON: The other part of it is do you want your code to predict the pool surface temperature so that you can couple it to the containment environment? That part is difficult.

MR. BERTA: We want to make very sure that we don't get a situation where we get a double break-through and we get steam pressurization.

MR. CATTON: And there's data that tells us what the circumstances are where the break-through will occur. That data was generated for MARK 1, 2, and 3. Some of it is in the PDR.

MR. BERTA: We have the LOFT data, which is also very good for that.

MR. CATTON: There's that program in Scandinavia somewhere, where they -- and there was also the Japanese programs. There's a lot of data available.

The only thing where the database is weak is that they're using these T-quenchers. A jet is very different than the T-quenchers.

MR. BEELMAN: What's a T-quencher?

MR. CATTON: The pipe comes down, splits out into a "T", and it's capped on both ends, and there are a bunch of holes drilled in it. It works the same. That way you get a whole bunch of little jets, and it really just makes it --

MR. SCHROCK: It works very effectively, but if the thing is too close to the surface and the amount of subcooling in the water that it's entraining and the steam discharge is not high enough, it's possible that they might get some steam venting to the surface.

MR. CATTON: That's right.

MR. SCHROCK: If they have done calculations that show there is really a problem if you start getting steam in the space above the thing, then somebody needs to show that that won't happen for the geometry that Westinghouse has in the AP600.

MR. BERTA: Anyway, to conclude this one, this is a funded effort this year. We are waiting to start it, waiting for the ATL design information on just what we're dealing with in these two plants.

MR. CATTON: Do the safeties dump in this pool as well?

MR. BERTA: I believe they do.

MR. CATTON: From the steam generators?

MR. BERTA: No.

MR. CATTON: They don't?

MR. BEELMAN: The safeties go directly to the containment.

MR. CATTON: They just dump the steam into the containment environment. Okay.

MR. BEELMAN: That's correct.

MR. CATTON: And these lines have air in them?

MR. BEELMAN: Yes. There's a vacuum breaker.

MR. CATTON: And you have to worry about the air-clearing process and everything else, I guess. There's a lot of stuff in the literature.

Why don't you continue?

MR. BERTA: The next item the steam separator. The model that's currently in LOFT -- or in the RELAP5 code -- is really non-mechanistic. In fact, I was surprised to see the words "black box" written in the RELAP5 manual for this.

So, it really is not at all applicable to the SBWR.

So, we were asked to provide an improvement in that area, primarily for the SBWR, and we also looked at the model in terms of the AP600 and the PWR geometry, and our recommendation was to put in the GE-developed model, mechanistic model, from the TRAC BWR code.

We proposed this to the NRC, and they approved that model for placement in the code. So, we do have a funded effort now to put that one in the code.

We also intend to put in the steam dryer model that was also developed by GE.

The analysis that we have done here on the PWR separator showed that this non-mechanistic model that we have currently in the code is probably good enough, except for possibly a steam line break.

We then looked at the models that were developed at MIT, and they have a very rigorous model, and they also have developed what they call a simplified model that depends upon -- they call it a switch model.

It depends upon the relationship of the liquid level in relation to a critical level that they define in the separator, and it was decided to recommend placing that simplified model as an option in the code for the PWR.

So, that entire effort is funded, and it is now currently underway.

MR. DHIR: Excuse me.

MR. BERTA: Sure.

MR. DHIR: This MIT model, is it verified through experiments?

MR. BERTA: Yes.

MR. ZUBER: Yes. Those were good experiments -- several years ago. So my question is, am I correct, then, you would have two modifications or two models, one from TRAC-B and one from MIT?

MR. BERTA: Yes.

MR. ZUBER: In the code.

MR. BERTA: In the code.

MR. ZUBFR: Okay.

MR. BERTA: We look next at the spherical accumulator. We wanted to add the capability of handling that type of geometry to the code. This one was a fairly straightforward one, as it turned out.

We created essentially a parallel coding for either cylindrical or spherical and placed it in the code as a user option. So, this one is actually being completed, and we have the documentation on it.

Of course, the spherical geometry gives you a variable cross-section area and variable surface area. So, we -- the heat transfer correlation had to be changed to allow for the surface area of the sphere.

The mass transfer correlation had to be modified to handle the interfacial area between the gas and the liquid, and then the acceleration terms in the equation and the liquid level tracking model had to be modified to account for the flow area and volume of the spherical geometry.

So, that was fairly straightforward, and it has been put into the code.

MR. ZUBER: How many nodes?

MR. BERTA: This is still the model that parallels the accumulator model that was in there with the cylindrical geometry.

MR. ZUBER: Okay.

MR. SCHROCK: What are you using for the heat transfer coefficient on the vessel?

MR. BERTA: I'm not sure.

MR. SCHROCK: It's not in the one we have.

MR. JOHNSEN: I'm sorry. Would you repeat that?

MR. SCHROCK: I asked what is the basis of the heat transfer coefficient that's used on the spherical vessel surface.

MR. JOHNSEN: The interior surface?

MR. SCHROCK: Isn't that the heat transfer we're talking about?

MR. JOHNSEN: I didn't know we were talking about heat transfer in particular.

MR. SCHROCK: What?

MR. JOHNSEN: I didn't think we were talking about heat transfer in particular, but that model is described in Volume 4.

MR. SCHROCK: In the one we already have?

MR. JOHNSEN: Yes.

MR. SCHROCK: For the spherical vessel?

MR. JOHNSEN: Yes. It doesn't, I believe, differ from the one for the cylindrical.

MR. SCHROCK: Well, natural convection on a vertical surface is different from natural convection in a dome. So, that's why I asked.

MR. JOHNSEN: I don't believe we changed it.

MR. CATTON: Is the heat transfer that important in the accumulator? I don't think so.

MR. SCHROCK: Well, it influences the pressure volume history. Isn't that why you do the calculation?

MR. BERTA: Yes. I was curious about why they would go to a spherical accumulator.

You would assume it was to get the -- maybe Ron can correct me on this, but I think that the only reason why we would go to a spherical accumulator is to reduce the surface-to-volume ratio on the gas, which would give you a more adiabatic gas expansion, which in turn would extend out.

MR. BEELMAN: That's not correct?

MR. BERTA: It's not?

MR. BEELMAN: Ron Beelman for EG&G.

We don't know exactly what the motivation for doing it was, but Westinghouse is clear that they wanted a spherical accumulator, because the incremental decrease in pressure per unit of mass discharged from the accumulator is the mass from a cylindrical accumulator.

So, they wanted a higher pressure in the accumulator for a longer period of time, which will be sustained as long as the level is above the mid-point of the sphere.

MR. CATTON: Makes sense to me, but I don't think the heat transfer is all that important.

Why don't you go on?

MR. BERTA: Okay.

The last item to discuss is the computational improvement for long transients.

As it turns out, this one is the one that generated the most excitement, I guess, if you will, because the developers are most interested and have been interested in this area for a long time, because RELAP5 and the RELAP series of codes has been with us for some time and has carried on a lot of things that were developed in historical terms.

The request was specifically to provide some reduction in the code run time in order that the calculations that could be up to three days real time could be calculated in a reasonable manner, and we had estimated that, from the experience that we've had with running the code, that we would like to see something on the order of a factor of 10 decrease in run time, which is a sizeable effort to accomplish.

MR. WILKINS: Would you mind giving me one more number? A reduction by a factor of 10 from what to what?

MR. CATTON: And relative to what?

MR. BERTA: I recall numbers like -- calculational times being as much as 23 times longer than real time or, in some applications, maybe five times longer than real time. So, we're looking at something that can handle that kind of a situation a little better.

MR. CATTON: So, for your three days, you still would be on the order of six, seven days of computation, even after your reduction by a factor of 10.

MR. BERTA: If we have the worst case, yes. We're still looking at fairly long times, but again, the factor of 10, that came from me. I'll take responsibility for that.

In order to make a proposal to do a lot of work in this area, we have to tell potential sponsors what they might get for it. If we don't tell them, they're going to come back and ask us what we can give them for the amount of money that we would be asking for.

So, again, the factor of 10 is really an approximate number. It's dependent on the size of the problem, it's depend upon the machines that you've got to work with.

MR. WILKINS: Did you consider just suggesting that you get it down to real time?

MR. BERTA: Our objective is real time, and I'll tell you why in a minute here.

MR. ZUBER: Let me ask you -- just trying to analyze and find out -- where does a computer computation spend most of the time?

MR. BERTA: Again, that varies. They looked at it and have come up with 60, 70 percent of the time being spent on the solver, the matrix solver. For other types of problems, where you don't have a lot of nodalization, the codes use that time in other areas.

So, again, it's dependent upon the type of problem that the code is working on.

MR. CATTON: For three days, you need a quasi-steady program.

MR. SHOTKIN: This three-day feature is sort of a red herring.

MR. CATTON: I understand.

MR. SHOTKIN: Certainly, after the first few hours, what's going on in the primary is not going to be really that detailed a calculation. It's the containment that's going to be the key, and RELAP could be reduced to very few nodes.

I don't think RELAP has to be increased a factor of 10 from its current modeling to go out to three days.

MR. SCHROCK: This means you need a new logic for time-step control in very long transients. When you get into this quasi-steady type of performance, have time-step control, it really marches ahead, instead of for all these detailed calculations, getting the same answer you got 10 minutes ago.

MR. JOHNSEN: Yes. I think we agree what Lou is saying. When we first started organizing thoughts in this area, we came up with over 60 things.

MR. BERTA: It was quite sizeable, our first cut at it.

MR. JOHNSEN: And certainly, amongst those 60 were simplifications in the modeling, recognizing that, once we get -- once you get out beyond several hours, it's a very slow process dominated by the containment.

So, that's going to be a major part of the speed-up, not just the code but how you're modeling the system.

MR. CATTON: We agree.

MR. BERTA: It turns out that there are two other organizations that also are interested in speed-up of the RELAP5 code. These are Bettis Atomic Power Laboratory and the Westinghouse Savannah River Laboratory.

As a result of their interest, along with the interest of the NRC, what we did was to make a proposal that comprised several elements that were grouped into those three areas, either the planning step, advancement, solution efficiency, and lastly, to take advantage of the current and future generations of computers and get into the parallel processing.

This kind of gives a better picture of what we're thinking of in terms of trying to get to real-time capability with RELAP5. Of course, the NRC wants to calculate very long transients, and they would like speed-up for that purpose.

Bettis, on the other hand, wants to have code speed-up, because at least they are potentially going to be dealing with system model sizes that are much bigger than what we have dealt with. They have talked in terms of something like 3,000 node type problems.

Bettis is also interested in other aspects of the overall speed-up process, which extends to the actual creation and modification of input decks and in the analysis, after the calculations are over with, being able to analyze the results more efficiently.

As you may know, Bettis and Westinghouse Savannah River Laboratory jointly funded the addition of the 3-D fluids model to the RELAP5 code, and Bettis has further funded the addition of a variable gravity vector, is what we've been told to refer to it as, for their code.

They are actually looking to have RELAP5 replace the PIRT code which they have been using up to now. So, they have been the main driver in asking for and extending the scope of this effort.

Savannah River Laboratory -- they are interested in code speed-up, at least in real-time capability, for using the code as a driver for simulators. I think that's an ambitious effort, but it's an interesting one to think on.

What we have proposed is work in these following areas.

In the area of time-step advancement, we wanted to go to an increased degree of implicitness in the code over what's currently there now, and this is in terms of the correlations and the models in this area.

That area, number one, has been divided further into four sub-tasks, and I'll get back to that in a minute.

The second item there is on the time-step control function. There's two items listed under that one. We have proposed and come up with a preliminary cost estimate for the time-step size.

This was to do a study on the method of time-step size, analysis of what's currently in there, having a double methodology that's currently used, to try to come up with a better one to increase that time-step size so that it runs more near to the material curant limit.

The second part there is one that we initially have not done a cost estimate on, at least on a preliminary basis, and that one was to allow or bring the code to the state where it could run operationally in either the nearly implicit mode or the semi-implicit mode.

Currently, it's operational in the semi-implicit mode and not fully operational in the nearly implicit mode.

That is a big-ticket item that we haven't -- we decided we didn't want to go into that. However, Bettis came back to us and said they want us to provide them with a cost estimate for that -- to do that work.

So, we have done that, but that's just recently been completed, and we have not conveyed that information to the NRC or to Savannah River as yet.

In the area of --

MR. WULFF: Before you go on, could I ask a question?

MR. BERTA: Yes.

MR. WULFF: With the time-step size, do you know now how much you are from the current limit during a transient on the average and how much you can gain from that?

Since the time-step is controlled by all cells, by the most limiting cell, the question is how much can you gain from this further attempt, and then I have a question on the second one.

MR. BEELMAN: The code is running at 100-millisecond time-steps right now, which represents about 1/7th of material curant limit. The material curant limit is about 700 milliseconds.

MR. WULFF: But that is not a constant.

MR. BEELMAN: No. It depends on -- especially not during ADS. During ADS, as the velocities increase, the curant limit goes down, but in steady state, which is a yardstick, if you like, the code is running about 1/7th of the material curant limit.

MR. WULFF: Okay. Thank you.

MR. JOHNSEN: You mean the most limiting cells.

MR. BEELMAN: Yes.

MR. JOHNSEN: That, again, is not necessarily relevant to the long period of time, after the first two hours of a transient, where we have very low flows.

MR. BEELMAN: After you get down to fourth-stage ADS, there is a very long period that we have not been able to successfully calculate very far out into. During that period of time, I wouldn't be surprised if the curant limit was on the order of tens of seconds.

MR. WULFF: Okay. So then I'll go on to the second question.

When you go to more implicitness or degree of implicitness, does your matrix not grow, the item that you mentioned a few minutes ago as being the most time-consuming part, and to what extent are you expecting computing time savings from going to an increased rank of your matrix to invoke whatever pressure inquiries you might want to use?

MR. BERTA: We're looking at about on the order of a factor of two increase we're hoping to see out of that part of it. I think Dick can clarify that a little.

MR. WAGNER: Two parts to that. There's two techniques in the code, the semi-implicit and the nearly implicit.

For the semi-implicit, the matrix is one equation per volume.

When we do the nearly implicit, there's several stages of solving simultaneous equations. The first one is two equations per junction, followed by -- I think it varies from three to five.

Well, it varies for the -- if you have non-condensable and the number of species of non-condensables, but that is of the same order as the semi-implicit; that is, one per volume.

The part where we want to, say, increase the implicitness to improve the robustness of the code would be like looking at the interphase heat transfer.

The equations tend to have the capital "H" or a big "H" you saw in some of the equations yesterday times a difference in the temperatures. The temperatures are already at "M" plus one or new time-step level through linearization.

The "H" can vary over, I think, nine orders or ten orders of magnitude as a function of void fraction. That is always used in a time value.

We're talking about linearizing that, and that set of operations will add terms to the existing matrix elements but will not increase the order or the number of non-zeros in the existing equations.

Then, another step is we currently have -- the heat conduction is explicitly connected to the hydro-dynamics. We can -- we believe, anyway, that we can bring the entire heat conduction to be implicit with the hydro-dynamics.

Now, at first glance, that looks pretty bad, but you're including an equation for every mesh point of every heat structure.

They're tri-diagonal in nature, because they're one-dimensional, and again, you will end up adding terms to the existing non-zero matrix elements that will not introduce anymore non-zeros in the matrix or add equations.

MR. WULFF: Thank you.

MR. BERTA: The FY '93 funding that we've got from the NRC includes some funds allocated to this effort, and those activities are underway.

The NRC has directed us to put their funding towards the time-step advancement developments, and we have allocated part of that funding to the nearly -- or making the improvements in the implicitness.

The funding we've put there will fully fund two of the four sub-tasks in that area.

The rest of the funding that they have given us we have put towards the time-step control function, and what they have given us provides 50 percent of the funding that's needed for that task, and that is Part A in that area.

We expect shortly, at least on the order of three to four weeks, to receive funding from Bettis.

We do not have indications yet of where they want us to concentrate their funds, but I think that they will pick up the other 50 percent of the cost of Part 2-A on the time-step control functions.

MR. SCHROCK: Vic, have you considered the possibility of using quasi-steady solutions in this long-term operation, instead of staying with the transient formulation?

MR. BERTA: Have we?

MR. JOHNSEN: Yes, we have. We haven't ruled that out.

MR. SCHROCK: I think that's where your real time saving is going to come.

MR. JOHNSEN: That was on the list.

MR. ZUBER: Did you rule it out or you are considering it? I didn't hear.

MR. JOHNSEN: I said we have not ruled that out.

MR. ZUBER: Okay. Okay. I didn't hear you.

MR. BERTA: Just to briefly summarize what's happening in the other areas there, on the solution efficiency, the current solver that's in the code is a sparse matrix solver that's known by the name of SISSOUL.

It has a lower operating count, but it is still fairly inefficient in handling the pressure matrix, and it does not allow for either vectorization nor parallelization.

So, what we propose to do is to add a number of solvers, the two types, the direct solvers, which we do have some experience with, and an iterative solver. We proposed adding two direct solvers, known as the TRBR solver and the BPLU solver.

The TRBR solver has been put into RELAP5 in an early, now no-longer-used version of the code, and it was compared with SISSOUL. There was significant reductions in the time to solve the matrix. The BPLU solver is expected to be even faster than the TRBR solver.

We have proposed putting both in, because we could get the -- at least, conceptually, we could get the TRBR solver operational within a relatively short time. So, it could be used fairly soon.

That would be followed by the BPLU solver. We're having second thoughts about doing that.

We may end up just adding the BPLU solver, because if, indeed, it proves out that it is the faster of the two consistently for all applications, then clearly the TRBR solver will not be used anymore, and so, we may then put that one in.

Then, in the parallel processing area, we would add that capability to the code to work on any number of parallel processors.

This area is mainly the one that Bettis is interested in, because they now have a Cray YMP, which has eight processors, and they are in the process of acquiring a new machine which has 16 processors.

So, they want to take advantage of that, which they cannot do with the current version of RELAP5.

So, I expect to see funding from them in that area, also.

MR. CATTON: Didn't we see an example yesterday of the use of parallel processing? You ran CONTAIN code on one and --

MR. JOHNSEN: Yes.

MR. CATTON: Under solution efficiency, number one, you have domain decomposition. Domain decomposition goes along very well with parallel processing.

MR. BERTA: Yes.

MR. CATTON: Is that the kind of thing you have in mind?

MR. BERTA: Yes. The reason they put that --

MR. CATTON: I understand domain decomposition for regular fluid mechanics problems. When you say domain here, what do you mean, that the reactor vessel might be one domain and another piece another domain and then you're going to --

MR. BERTA: The idea here is to restructure that pressure matrix so that all of the 3-D components are numbered consecutively, followed by consecutive numbering of the 1-D pipe components, followed lastly by the "T" elements and the time -- input time elements.

MR. CATTON: Put each one of those on a different CPU?

MR. BERTA: Yes. Then the -- see, the current solver doesn't care, it doesn't do that, but there's other solvers that can take advantage of that by breaking down that pressure matrix.

MR. CATTON: This is also something that you could do very effectively on some of the modern workstations with multiple CPUs.

MR. BERTA: I believe we do have a workstation with two CPUs.

MR. MOUSSEAU: Vince Mousseau, EG&G.

We are currently doing some work in distributing across a system of workstations on other simpler codes.

The main thing we're looking at, the domain decomposition, is for the larger decks, where you have multiple, three-dimensional components, possibly multiple two-dimensional components, plus a large number of one-dimensional components, restructuring your matrix so you can separate those three-dimensional components out, which gives you a good breaking place for splitting things across different CPUs.

MR. CATTON: That's a very effective method that's used in the aerospace business, but it's a different kind of problem. But I guess, once you have it in a matrix, it's just a matter of where you draw your lines.

MR. JOHNSEN: I might add that our most recent experience is the cheapest way to make the code run faster is to buy a new computer.

MR. CATTON: That's probably right.

MR. JOHNSEN: We gave the code to IBM recently and asked if they could play with it and see how fast they could make it run on their model 580, which is about a $60,000 machine. It runs as fast as it does on a Cray.

MR. BOEHNERT: As fast as a Cray?

MR. JOHNSEN: Yes.

MR. CATTON: Oak Ridge -- I guess it's a fellow at the University of Tennessee -- keeps a running compilation of time for computation for a set of standard problems, and you can actually get it via Internet.

MR. BEELMAN: It's Don Guerra.

MR. CATTON: Yes. And that's a nice thing to read once in a while. It really wakes you up. Cray isn't always at the top.

Is that the end of your talk?

MR. BERTA: Yes.

MR. CATTON: Thank you very much.

Let's continue to the next one. Gary Johnsen, IRWST behavior when PRHR operates.

MR. JOHNSEN: I'm going to talk briefly about the difficulties that we have encountered in modeling the PRHR; well, specifically the IRWST when the PRHR is functioning. We don't have a set of solutions at this point. So, I'm really just apprising you of what the issues are.

MR. CATTON: That's what we want.

MR. JOHNSEN: The modeling of this particular component is sort of a new challenge for a code like RELAP, where we have a large pool of water, the nature of which is more of a three-dimensional or even -- or at least two-dimensional body of water that sits inside the containment, only a portion of which is in the vicinity of the tube bank that represents the PRHR, which carries coolant from the primary coolant system, in a natural circulation mode, through the IRWST.

Now, the actual nodalization of that tank presently looks like this.

MR. CATTON: This is single-phase, isn't it, on the reactor side?

MR. JOHNSEN: No, it can be two-phase.

MR. CATTON: Is that two-phase in those tubes?

MR. JOHNSEN: Two-phase natural circulation.

This is what the nodalization looks like right now. This channel here represents the IRWST in the vicinity of the PRHR tube bank, whereas this channel here represents the rest of the pool, so that we're mocking it up presently as a two-dimensional arrangement.

MR. DHIR: How do you know where to draw the boundary?

MR. JOHNSEN: We don't. We don't. That's one of the problems. That's one of the problems. So, the issues --

MR. CATTON: What you're doing here, then, is you're just going to cut it up into slabs that run all the way from one side to the other?

MR. JOHNSEN: You're talking about the heat structures?

MR. CATTON: I'm looking at 802-6. Is that fluid?

MR. JOHNSEN: Yes, that's liquid, and this would be the containment atmosphere.

MR. CATTON: Okay. So, you are, you're just slicing up the pool.

MR. JOHNSEN: That's right. We're slicing up the pool.

MR. SEALE: And the 802s are a full cross-section of the pool.

MR. JOHNSEN: So are the other ones.

MR. BEELMAN: No.

MR. JOHNSEN: Do you want to explain that?

MR. BEELMAN: The IRWST proper was divided into three separate bays that are under the influence of two separate systems.

As you may be aware, the steam generator compartment juts out into the IRWST proper substantially, isolating the sparger side from the PRHR side, but there is a buffer zone between the two of them, about 13 feet in width.

MR. CATTON: Of what, water?

MR. BEELMAN: It's water, yes. The tank is 530,000 gallons, and it has 28 feet of liquid head.

Now, what was done was, because the sparger comes in at essentially the 10-foot elevation below the surface, there was a node line, because we wanted the sparger to be in cross-flow but not up to momentum.

We didn't want to blow the water out of the tank, as the code would normally do. So, the node line on the top was drawn because the PRHR is only submerged by six inches.

There's only six inches of water above the top of the PRHR heat exchanger.

MR. CATTON: That's above the top of the heat exchanger.

MR. BEELMAN: Above the top of the heat exchanger, above the horizontal section. If you've seen it at Westinghouse, you know that it approximates a "C" shape.

There is actually 671 three-quarter-inch tubes in each of two heat exchangers that come in horizontally from a head, a tube sheet which is somehow bolted onto the concrete wall of the IRWST.

The pitch then goes from one-by-one to three -- excuse me -- one-half-by-one-and-a-half to three-by-one-and-a-half as it bends down into a vertical heat exchanger, and then, of course, about five feet from the bottom of the tank, they bend back and head out and connect to another header or a tube sheet which is connected on the IRWST wall again.

MR. CATTON: And it's all up pretty tight to the wall.

MR. BEELMAN: No. There's about five feet --

MR. CATTON: Five feet out from the wall?

MR. BEELMAN: Once you make the transition to the vertical section, there's about a five-foot gap between the nearest tube to the wall and the wall.

MR. CATTON: Okay. That's going to lead to a highly stratified flow. You're literally just going to pump hot water up onto the surface.

MR. BEELMAN: Well, we see very active natural circulation.

MR. CATTON: But that water is going to go up, and the hot water is going to stay on the top.

MR. BEELMAN: Yes.

MR. CATTON: So, you're going to have to either -- you're going to have to treat that as a multi-dimensional problem, and I would not use a finite difference solution.

MR. BEELMAN: Hopefully, the final stratification model will lend some help in this regard.

MR. CATTON: Some of your simple plume-rise-type models would really do a number on this problem.

MR. BEELMAN: Yes. Someone yesterday thought that the IRWST was going to be a fairly quiet surface. It is going to be a very active surface when these two heat exchangers fire up.

MR. CATTON: That's all right. You still could use a plume-rise model.

MR. BEELMAN: Yes.

MR. CATTON: And just let the steam that escapes escape.

MR. BEELMAN: No.

MR. CATTON: That way you'd have something that's not going to eat up a lot of computational time.

MR. BEELMAN: The model is running fairly efficiently right now. The problem we're having with it has to do with air, and Gary can touch on that.

Gary, will you pull up your previous slide?

Let me point out that all the nodes that you saw in that previous slide are actually tank nodes. None of them are PRHR heat exchanger nodes.

MR. CATTON: Tank nodes.

MR. BEELMAN: What we have actually had to do is treat the PRHR heat exchanger as essentially a once-through steam generator, so that we gave it an actual secondary side within bay three of the IRWST.

So, after we had sectioned the IRWST into the sparger bay, a buffer bay, and a PRHR bay, we had to model the secondary side of the tubes in order to get "T" infinity correct.

MR. CATTON: Okay.

MR. BEELMAN: Okay? So, 803-7, -9, -11, and 804 and 805 are the secondary sides of the PRHR heat exchangers, and they are connected. It's a very difficult problem for the code, the first time it's ever been attempted, because this is a free-flooding heat exchanger.

It floods from the sides as well as convecting fluid from underneath as you get boiling and you set up these convection currents. It's a very difficult problem.

MR. SEALE: So, where is the 802 stack?

MR. BEELMAN: 802 is the PRHR bay.

MR. SEALE: In the pool.

MR. BEELMAN: In the pool, yes. The buffer is 801, and the sparger bay is number 800, and you will see that, I think, in one of the nodalization diagrams in some presentation.

MR. LAUBEN: So, that's not the whole --

MR. BEELMAN: That's essentially a third of the IRWST problem.

MR. ZUBER: The buffer is 801?

MR. BEELMAN: No, no, no, no. The sparger bay is number 800. The buffer bay is number 801, and that's not up there.

MR. ZUBER: Yes. Okay.

MR. BEELMAN: The bay that you see, the PRHR bay, is number 802, and the secondary side of the PRHR, which is a subset of the PRHR bay, is numbered variously, 803-7, -9, -11, -4, and -5.

MR. JOHNSEN: The issues that have been identified, that Ron has touched on --

MR. BEELMAN: 804 is the secondary side of the vertical section of the PRHR heat exchanger.

MR. JOHNSEN: As Ron has suggested, one of the main issues is how do you properly calculate the recirculation of feedwater in the vicinity of the PRHR?

It's a multi-dimensional flow pattern where you have cooler water coming in to replace the warm water and steam that's being generated.

MR. CATTON: This is the kind of problem that people dealt with in cooling ponds and everything else. It's just that your hot-water pump is going to be a little bit more vigorous because it's one, but you draw all the water in from far away. So, it's a horizontal flow.

So, you can still treat it as a one-dimensional problem.

MR. BEELMAN: That is not what the code has indicated thus far.

MR. CATTON: Well, I'm not too concerned with what the code is indicating, but if you have this thing stuck into a big pool, what it's going to do is draw the cool water in, and it's going to rise up and lay on the surface.

MR. BEELMAN: Believe it or not --

MR. CATTON: Until you establish a temperature gradient, the top is pinned by the interaction with the containment.

MR. BEELMAN: The velocities being domered from the cell underneath any particular node in contact with the heat exchanger far exceed the domering from the sides of the lateral aspect of the IRWST.

Now, we've done sensitivity studies.

MR. CATTON: Could you put up that node diagram? I get lost in your description. Which node are you talking about?

MR. BEELMAN: The vertical flow up the stack, up the 804 stack, is much higher than the cross-flow coming in from the 802 stack, which is the balance of the tank.

MR. CATTON: Sure, because the one going up the 804 stack is integrated, and there is an entrainment process going on.

MR. BEELMAN: That's correct.

MR. CATTON: But the actual velocities feeding in from the side are smaller, should be smaller than the 804 or you're doing something wrong.

MR. BEELMAN: That's right, and what you actually see going on here is a big circle. That's what it's doing.

MR. CATTON: Yes, but what you'll find is that the hot water hits the surface and flows across the surface. It won't come down again, and then your whole temperature gradient will sink into your pool.

MR. BEELMAN: Right, and that's a problem for the code right now.

MR. CATTON: Yes, and it will be a problem for this kind of a code. You would be better served to use some of the school modeling and not try to force it into a finite difference model, a more empirical approach if you wish.

Okay. Thank you.

MR. WULFF: Can I ask a question about how the impedances are calculated between the bays, the cross-flow? You must have some junctions representing the flow, and I don't see it on that side and then on the 801, between the 801 and 802 and the 800 and 801.

What is your impedance, your friction or form loss or whatever you use to connect these flows? You can play a big game with this.

MR. JOHNSEN: We don't put any form loss in those junctions.

MR. BEELMAN: That's not correct. Data was taken for essentially horizontal flow across tubes.

MR. JOHNSEN: I think he's talking about the free area.

MR. WULFF: The free area.

MR. JOHNSEN: The free area?

MR. BEELMAN: The free area in bay three proper, in the vertical direction, has no form losses whatsoever. That's a uniform cross-section.

MR. JOHNSEN: There's no form losses on the connections made on this face. On this face, I think what Ron is saying is the tube bank is in this column, and therefore, the resistance to the flow is based on flow that's normal to a bank of tubes. Is that correct?

MR. BEELMAN: That's correct.

MR. JOHNSEN: So, there is a resistance --

MR. WULFF: That's not my question. I can see that you can calculate the shear between the tube and the flow outside the tubes and also inside the tubes, but what I am asking for is how you calculate, how you represent friction in the lateral flow between bays 800, 801, and 802.

MR. JOHNSEN: We don't.

MR. BEELMAN: The only thing that's represented there is the wall drag. That's all.

MR. CATTON: But there is no wall. It's fictitious.

MR. WULFF: There is no -- yes.

MR. BEELMAN: The tank has a wall.

MR. WULFF: But only at the bottom.

MR. JOHNSEN: Well, you're talking about the sides.

MR. WULFF: And the sides, yes.

MR. JOHNSEN: Yes. That's true. That's true.

MR. WULFF: So, how is the shear --

MR. JOHNSEN: But there's no form -- there's no form loss, you know, on the connections over here.

MR. WULFF: Well, if you don't represent this as a continuum with shear, you represent it by junctions and nodes, and you have to make, somehow, the connection that the junctions represent what the shear will do in the continuum.

MR. JOHNSEN: Well, there's no requirement to have a form loss at a junction. As Ron said, the wall drag is going to be there as a volume.

MR. WULFF: Not in the open pool. There is no -- in cells that are not in contact with walls, there cannot be wall shear.

MR. JOHNSEN: Okay, but all these sides do, in fact, have two walls, correct?

MR. BEELMAN: Except for the secondary side of the heat exchanger. Every cell in 800, 801, and 802 connects to a wall.

MR. JOHNSEN: Yes.

MR. BEELMAN: But the three bays in the IRWST are cross connected in cross-flows, so that basically what is modeled is just a level-seeking device. That's all that's modeled.

MR. JOHNSEN: In other words, this face here of the cell, as well as the one on the opposite side, are in fact in contact with the wall and the pool.

MR. WULFF: Yes, but that does not represent the --

MR. JOHNSEN: This represents the entire width of the pool, if you will, in this direction.

MR. WULFF: And where is the shear that is on the top and bottom surfaces of that very cell?

MR. BEELMAN: They are not represented. It is represented as simply a level-seeking tank. That's all.

MR. WULFF: Okay. No further questions. Thank you.

MR. SCHROCK: Gary, I have just one kind of unrelated question.

MR. JOHNSEN: Is it on this particular slide?

MR. SCHROCK: No, just a general question. Is the primary fluid flowing upward or downward?

MR. JOHNSEN: Downward.

MR. SCHROCK: Downward. Thank you.

MR. JOHNSEN: The hottest fluid is at the top of the IRWST.

So, the kinds of issues we have identified thus far are the recirculation of the IRWST water in the vicinity of the tube bank; partial uncovery of the tubes -- if we boil enough coolant away in the IRWST to drop it below the top of the tubes; what is the best way to nodalize the

IRWST; and then the problem that Ron mentioned earlier, which is we're getting code failures due to faulty domering of air into the IRWST.

MR. DHIR: Excuse me. I see several issues which are not listed on this view-graph --

MR. JOHNSEN: Okay.

MR. DHIR: -- which come to mind.

One is that you could have, on the primary side, either single-phase or two-phase. So, you need to have, for two-phase, correlations with heat transfer.

MR. JOHNSEN: That's already in the code.

MR. DHIR: Then you are putting heat into the wall --

MR. JOHNSEN: Yes.

MR. DHIR: -- with two-phase steam --

MR. JOHNSEN: It's already in the code.

MR. DHIR: Okay.

MR. JOHNSEN: I mean we've modeled the PWRs undergoing single-phase, two-phase, and reflux natural circulation, which involves two-phase flow over the top and down in --

MR. DHIR: Secondly --

MR. JOHNSEN: -- the steam generator.

MR. DHIR: -- you need to have the heat transfer coefficient on the secondary side and also to see the margin you need for critical heat flux on the secondary side, especially at the top, if it flows from the top down.

MR. JOHNSEN: Yes. Yes. You know, whether or not the correlations we have in the code right now are completely suitable for this tank situation is something we need to check into.

MR. CATTON: Did you get your correlations from the steam generator work for this?

MR. JOHNSEN: No.

MR. CATTON: No. You're just using --

MR. JOHNSEN: From the steam generator? No.

MR. CATTON: That might be a place for you to look. I recollect an NRC program that measured these sorts of things.

MR. SHOTKIN: Westinghouse is running a separate effects PRA trial. We hope to use the -- or apply the code to that data and run correlations based on that data.

What you might be interested in doing, when you review the Westinghouse program, is look at the scaling of the Westinghouse test.

MR. DAVIS: What is the scale?

MR. SHOTKIN: You mean the number of the scale? I don't want to give an opinion on it, but I just ask you to look at that.

It's fairly small, but I'd ask you to look at whether it's representative of the processes that you've heard about occurring, what we think are occurring, and see whether they've been able to capture that.

MR. ZUBER: How do you feel about ROSA-IV on this?

MR. SHOTKIN: We put a special effort into -- because of our concern about the data, we did put a special effort into designing the PRHR in ROSA-IV, for ROSA-V, and I don't know whether Novak agrees, but our feeling is that ROSA-IV is going to give very good scale data for the PRHR.

MR. CATTON: In this particular case, the PRHR, the a[illegible]t ratio will be important, because that's what's going to determine the temperature profile that the tubes see locally, and if you don't have enough for the height of your tubes, it could shift the heat transfer.

I don't know if that's important. It depends whether you're heat-transfer-controlled or not. I don't know.

MR. ZUBER: Let me ask you, in that document on scaling, is this addressed?

MR. JOHNSEN: The PRHR?

MR. ZUBER: The IRWST. Is it addressed in the scaling document?

MR. JOHNSEN: For ROSA?

MR. ZUBER: Yes.

MR. JOHNSEN: Yes.

MR. ZUBER: Yes, okay, for scaling in ROSA. It is addressed.

MR. CATTON: Okay, Gary. Onward.

MR. JOHNSEN: Yes.

Let me just briefly explain what we mean by this last issue. Even though this isn't the nodalization that's actually used, it serves to illustrate the point I'm trying to make.

What happens, when this -- when it was first nodalized this way, at least in this direction, where there are three or more zones like this, when the PRHR begins to activate and circulate hot coolant through here, actually what happens is that this calmer water becomes less dense and warms up, boiling occurs, and the tendency, then, is for the pump to replace this water here from this column over here.

So, the flows are in this direction from this column of water here, and that causes a net flow in this direction, downward in that column of water, and what the code is doing is it's domering some of the containment air to the cell beneath where the level is, and that causes the code to fail.

MR. CATTON: Let me offer a comment, Gary. If that's what's occurring, the code is not treating the problem right, because that column that's around those tubes should feed all the way across to the far wall, and then the whole --

MR. JOHNSEN: It should what?

MR. CATTON: It should feed hot water -- the hot water will literally run across the surface until it hits that far wall, and then, the whole level of the hot water layer will just get thicker and thicker.

MR. JOHNSEN: Well, I think it's doing that, isn't it, Ron? Isn't it sending the hot water across this cell here?

MR. BEELMAN: No, the code can't do that, Gary. When the two-phase fluid on the secondary side of the heat exchanger exits, it is in -- it's very near the top of the pool. So, it wants to flow out.

Now, unfortunately, the code does not know how to thermally stratify that from the colder fluid in the tank proper beneath it.

So, what it does is it just sets up a vector of air saying that, hey, the velocity in this top node of the tank proper has got to be downward in order to replace the fluid that has now been drawn into the heat exchanger itself.

Now, in doing so, it does not differentiate between a thermal buffer layer at the top, which you correctly describe, and just the volume average temperature.

So, it just circulates the whole tank.

The code does not have a capability --

MR. CATTON: And if you want to monitor IRWST properly, you're going to have to fix that, and if the code won't do it, you ought to develop yourself some sort of quasi-analytic model.

MR. JOHNSEN: I'm just explaining what the problems are. We don't have a solution.

MR. CATTON: I understand.

MR. SCHROCK: Ivan, we did some experiments of this kind, and it's exactly as you described it. The layer is very uniform in thickness, comes down very uniformly. We have published a model, and I'll give you the reference for it.

You may like it for this application, you may not, but it follows up earlier work that's been in the literature for a long time. This is a problem that's been around and researched fairly extensively. It's not new, but you cannot calculate it with any finite difference code.

COMMIX will not do this properly. Numerical diffusion kills it.

MR. CATTON: If you put enough nodes into it, you can do it, but I'm not sure you want to pay for it.

MR. BEELMAN: You can approximate it if you build a number of nodes in.

MR. SCHROCK: The physics of the problem are so simple, it's just insane to be doing a detailed finite difference calculation. It's very simple. It's almost continuity.

MR. CATTON: It's a very simple thing to do. As a matter of fact, Virgil will even put some notes in his report.

Virgil, if you could include in your report references and so forth, so that when we communicate it to these people, they understand.

MR. ZUBER: Let me make a comment, Ivan. You are directing the research, and that's a no-no.

MR. CATTON: I'm being responsive to a request.

MR. BEELMAN: He hasn't told us anything that we haven't though of already.

MR. ZUBER: Okay. Good.

MR. CATTON: You know, I knew that.

MR. ZUBER: Gary, let me ask you. You have these three horizontal nodes. One is for the PRHR, one is the buffer, and the left-hand side is for the sparger. Is that correct?

MR. JOHNSEN: I think that's correct, isn't it, Ron?

MR. ZUBER: Where is the sparger located?

MR. JOHNSEN: We have three zones or four zones in the IRWST?

MR. BEELMAN: I'm sorry. I have a hard time understanding you.

MR. ZUBER: You are not the first one to say that.

You have three nodes horizontal, and you have three zones. You have a sparger zone, you have a buffer zone, and you have a PRHR zone.

MR. BEELMAN: No. Don't read anything into Gary's little schematic right here, okay? Do you have the nodalization in front of you? I mean a real nodalization of the whole plant.

The IRWST is that shaded thing up at the top center of the diagram. Does everyone see that?

MR. ZUBER: Yes.

MR. BEELMAN: Okay.

Now, you can clearly see the three bays. Node 800 is on the left-hand side, and it's a stacked column of 10 or 11 nodes. I can't remember now. The buffer zone is numbered 801, and it's that central stacked column in the IRWST.

The PRHR is that zone which looks broader than the other two. It does not imply that it's bigger than the sparger bay. We just needed more room to put the PRHR heat exchanger in that depiction.

And it's numbered 802, so that the secondary side, then, is shown submerged in bay three proper, number 802.

Now, if Gary would put his picture back up, you will see the correlation between bay three and what he is showing you.

So, 802 is that third bay that I described as being broader, and nodes 803-7, -9, -11, all of 804 and 805 are the secondary sides of the heat exchanger, and they communicate only with bay three proper, which is numbered 802, okay? The heat exchanger is submerged in that bay.

MR. ZUBER: And 802 communicates through 801?

MR. BEELMAN: That's correct, in cross-flow junctions.

MR. ZUBER: Okay.

MR. BEELMAN: Gary's drawing leaves something to be desired, in my opinion, but I mean it serves its purpose.

MR. CATTON: Gary, did you hear that? You have to improve your graphics.

MR. JOHNSEN: I'm used to it.

Okay. So, let's just summarize where we are right now. I am anxious to look at the material that Virgil can send us.

We can get a successful calculation if we make the IRWST one huge node, basically, one stack of nodes, so that there is no division geographically from the zones that Ron described. What we're doing, of course, is we're heating up the entire pool.

MR. CATTON: It doesn't selectively heat the top?

MR. JOHNSEN: In the axial direction, it does the right thing. In the radial direction, if you will, or in the direction away from the tubes, it's heating up all the fluid. It's as if you took these lines out here -- and this is a node and that's a node and that's a node.

So, what it's going to do is the heat exchange that occurs here will heat up this entire level here --

MR. CATTON: Yes.

MR. JOHNSEN: -- and so on.

MR. CATTON: That's what it's supposed to do.

MR. JOHNSEN: Pardon?

MR. CATTON: That's what it should do.

MR. JOHNSEN: But in reality, it's going to be localized here, and this area here will be much cooler.

MR. CATTON: Oh, okay.

MR. JOHNSEN: We're starting at the next level down.

MR. CATTON: It gets heated all the way across?

MR. JOHNSEN: All the way across.

MR. CATTON: If you just shut off the connection in the vertical direction, you might be better off.

MR. BEELMAN: We tried that.

MR. CATTON: I mean selectively shut it off.

Okay.

MR. JOHNSEN: Okay. I mentioned the problem with the air, which is obviously wrong, and we'll do further diagnostic work, but I think the point that the one-parameter approach might ultimately be the best is something we need to look at.

MR. CATTON: Okay. Thank you.

It looks to me like this is a good time for a break. We'll return at 20 after.

[Recess.]

MR. CATTON: Can we get started? I'd hate to lose all the time we gained by starting at 7:30. It was painful for some of us.

MR. JOHNSEN: This particular topic was put on the agenda on the belief that there was a specific concern on the part of the subcommittee on the ability of RELAP to calculate horizontal countercurrent flow.

I might just pause and get confirmation that there was, indeed, a concern about this. Is that true, Ivan?

MR. CATTON: What's that?

MR. JOHNSEN: There was a concern on the part of the subcommittee about the ability of the code to calculate horizontal stratified --

MR. CATTON: Yes.

MR. JOHNSEN: Okay. So, that's why this is on the agenda.

The basic hydro-dynamic model is inherently able to predict countercurrent flow both in vertical and horizontal components of the fluid conditions appropriate to that situation prevail.

The conditions that need to prevail and be detected by the code are, first of all, that in a horizontal component we have stratified flow, and in RELAP, that is determined by using the Taitel-Dukler Criterion for that flow regime.

Secondly, we must have a liquid level gradient in the horizontal direction so as to cause the liquid to flow in the direction of diminishing levels of liquid in the axial direction.

Obviously, there has to be a pressure gradient in the other direction, as well.

Now, what I'm going to show you are a couple of cases that illustrate the capability to handle this.

The first one is really what we call a thought problem.

It's just a conceptual problem -- there isn't an experiment involved -- in which we have a pipe that's modeled with .20 volumes in the axial direction, horizontally oriented, and we start the problem off with this level of liquid diminishing from right to left, and then, above that, we have gas.

MR. DHIR: Excuse me. What kind of boundary provision do you impose on the two ends?

MR. JOHNSEN: They're closed. These are closed. We have a closed pipe that has this initial axial liquid level gradient, and then we start the problem --

MR. DHIR: It's mounted to the --

MR. JOHNSEN: Yes, in a way it is. That's correct.

Then we start the problem and allow the flow to proceed as the code calculates the flow from one end to the other.

The next two slides show the calculated vapor and liquid velocities. Here are the calculated vapor velocities at the ends and middle of the pipe as a function of time, and as you might expect, the maximum flows occur at the middle, and the two ends have diminished flow rates.

MR. ZUBER: I thought it was a closed pipe with liquid, then you displaced the liquid at one end.

MR. JOHNSEN: Right.

MR. ZUBER: Okay. That was the situation. So, what is the velocity you calculated?

MR. JOHNSEN: This is the velocity --

MR. ZUBER: And where is that velocity, in which direction?

MR. JOHNSEN: What I'm showing you on this plot here are the vapor velocities at this end, this end, and middle.

MR. WULFF: In a positive direction from left to right?

MR. JOHNSEN: I don't recall that.

MR. WILKINS: In any case, the velocity vector is in the axial direction.

MR. JOHNSEN: Oh, yes, yes, yes. This is a one-dimensional calculation. It's a one-dimensional calculation. So, the velocities are in this direction.

Now, the corresponding liquid velocities at those same locations is shown on the next slide. It shows the same pattern. I can superimpose these two. It's showing that the liquid and vapor velocities are exactly 180 degrees out of phase, which is what you'd expect.

MR. SCHROCK: That's nice, but why does it relate to CCFL?

MR. JOHNSEN: Not CCFL.

MR. CATTON: Stratified flow.

MR. JOHNSEN: That it's horizontal countercurrent flow.

MR. SCHROCK: Okay. I thought you were looking for the limitation.

MR. JOHNSEN: No, no, no.

MR. SCHROCK: Just the ability to --

MR. JOHNSEN: Just to do horizontal countercurrent flows, the issue as we understood it.

MR. CATTON: There is another half to the issue, and that is that, if you go back to your pipe and if I put a break in the top and it's a small break, I should get just pure vapor. Will I?

MR. JOHNSEN: If you --

MR. CATTON: The concern is not that you can do these kinds of calculations but that you really don't have a level in the pipe.

Now, maybe you do, I don't know, but my recollection -- when I looked at this some time ago in TRAC and also in RELAP5, it states you're using the same field equations, and all you've really done is adjusted the area and taken care of the interfacial drag and so forth, so you, indeed, do get this kind of behavior.

MR. JOHNSEN: Well, to a certain extent what you say is true. I mean, for example, there's still a single pressure involved here, even though, in reality, there is a pressure gradient in the "Y" direction, if you will, in this direction, okay? But there's still the same pressure.

Adjacent cells that have different levels create an axial force to cause the flow to proceed in that direction.

MR. CATTON: I understand that.

MR. JOHNSEN: Well, going back to your other question about the break --

MR. CATTON: If I put a break in the top somewhere, say down in the left-hand end, I'm going to get some of the two-phase mixture out.

MR. JOHNSEN: Right here you mean.

MR. CATTON: Yes, or anywhere along the top.

MR. JOHNSEN: Well, if the user evokes the model that Tom Baratta had mentioned yesterday, which is the off-take model, then what is dowered out of any cell that has a break in it or a leak in it or whatever you want to call it is going to be a function of the orientation of that hole relative to the liquid level in the cell.

MR. CATTON: So, do you back out the liquid level in that cell?

MR. JOHNSEN: Yes. Yes. You have to to put in the momentum transfer, I mean the pressure force from cell to cell. You have to calculate a level in that cell, and that's what we're doing.

MR. CATTON: So, you use the Dukler-Taitel flow regime map.

MR. JOHNSEN: Right.

MR. CATTON: You say it's stratified flow.

MR. JOHNSEN: You say it's stratified.

MR. CATTON: Therefore, we calculate a level in all cells.

MR. JOHNSEN: Right.

MR. WULFF: Could I ask a question? Are these diagrams showing the whole pipe?

MR. JOHNSEN: I don't understand your -- it shows the velocities at the center and the two ends. If you notice, there are a total of three traces on these two plots.

MR. WULFF: All right. Why is there no symmetry? On one end, you have zero flow, because it's closed, and the other is also closed, but you don't have zero flow.

MR. JOHNSEN: These two are the first junctions in from the end of the pipe.

The second illustration I want to give you is --

MR. CATTON: Just one more question, then we can leave this.

MR. JOHNSEN: Yes.

MR. CATTON: I understand now how you deal with the break flow. If you're creating a liquid level in there, you have the information you need to get all the areas right.

MR. JOHNSEN: That's correct.

MR. CATTON: But you don't do that.

MR. JOHNSEN: No. Typically, when you model the pipe in terms of its ability to exchange heat with the coolant, you use a single heat structure for each of these cells, and it is a radial heat slab, in effect, for the liquid in the pipe, and that communicates, in terms of the heat transfer, based on cell average or average properties.

So, it doesn't recognize the level as far as the heat transfer.

MR. CATTON: If it comes to heating away from -- under these kinds of circumstances, you just happened to get it right.

MR. ZUBER: There is a partition. Part of the energy goes to the liquid, and part of the energy goes to the level.

MR. JOHNSEN: Right. And it's true, the heat transfer is treated pretty much on the basis of a homogenous mixture, rather than a separated one, but you know, typically, the heat exchange with the pipes isn't very significant.

MR. ZUBER: This heat transfer process is important. This is an issue, and the way you are doing it, you are testing the physics now, and the physics was not important for the large break.

Here it is important in condensation, and the reason you have the water in this condition is completely based on -- is a consequence of this approach, and any process which depends on the heat transfer where you have two phases will be distorted, and I think this is difficult.

MR. SHOTKIN: Just help me. I'm sure you said it, maybe I missed it, but why is it going to be distorted?

MR. ZUBER: Because you are not calculating the condensation part of it. It's a single phase. On the top, you will also have a single phase.

MR. SHOTKIN: You're hooking together yesterday's presentation with this.

MR. ZUBER: Because it's the same problem.

MR. JOHNSEN: Let me just say that this particular presentation was not looking or not examining the heat transfer.

MR. ZUBER: I know, but --

MR. JOHNSEN: It's examining the hydro-dynamic model and whether or not it can calculate countercurrent horizontal flow, okay?

MR. ZUBER: Okay. And we're very satisfied in the results, and I have no quarrel with hydro-dynamics.

MR. CATTON: Actually, I'm impressed.

MR. JOHNSEN: Whether or not the heat transfer is important is something that's not demonstrated.

MR. ZUBER: But you calculate heat transfer when you have circulated flow, and it is a circulated flow, and this is my point.

MR. CATTON: Your condensation heat transfer in this is going to be extremely high. The heat transfer to the liquid is going to be very low.

MR. JOHNSEN: The presumption seems to be that this pipe is going to be cold, and under what circumstances is that going to be the case?

MR. CATTON: How do you know? It could be hot, could be cold, who knows?

MR. JOHNSEN: In a LOCA situation, the pipes start out hot.

MR. ZUBER: I just wanted to illustrate where your problem is.

MR. SHOTKIN: That problem is based on yesterday's presentation on the condensation. The problem is from yesterday's presentation, not from anything that Gary has said.

MR. CATTON: No, no. What he did today, showing hydro-dynamics, answers the questions I had before. The reason I raised the questions about the countercurrent stratified flow is for the other part of it.

If you can calculate it right and you're doing the heat transfer based on the surface area seeing vapor, surface area seeing liquid, you're all right, but you've got a generic heat transfer package that doesn't do that.

So, you're calculating part of the problem right, but you're not doing the other part right, and here, where you have the separated flow, it's clean. You might make arguments in some of the other areas of complexity, but here it's clean. He knows what the surface is he's calculating.

MR. SHOTKIN: And it's for condensation, not for boiling.

MR. CATTON: I think boiling would be the other way around. In boiling, you'd have a very high heat transfer to the liquid and very low to the vapor.

MR. JOHNSEN: Right, but I think the history on this, if I might just inject that, is that, typically, horizontal components are not heat transfer components.

There's stored energy in the pipes, certainly, that is released, but that plays a minor role, usually, in most transients.

MR. CATTON: If that, indeed, is the case and, for these long three-day transients, we are not worried about this sort of thing, then there is no problem.

MR. SHOTKIN: The PRHR has the two horizontal components.

MR. JOHNSEN: Yes, it does, and that was an issue of the level dropping in relation to the tube bank. It is an issue.

MR. SCHROCK: You've got these five-foot long horizontal tubes on top of this PRHR.

MR. JOHNSEN: That's what Lou just said, yes.

Let me just finish up this part, so we don't fall behind.

The other example I was going to show is a comparison to data.

In this case, we're looking at the French BETHSY facility, in which experiments were carried out to examine the three phases of natural circulation, and this first plot shows the measured and calculated downcomer coolant flow rate in the BETHSY facility as a function of the mass in the system.

So, what they did in this experiment was start with a full system, gradually empty it, and watch the different phases of natural circulation occur, start out with single-phase natural circulation, go into two-phase natural circulation which peaks, and then eventually get down to this part, of which we have reflux natural circulation, where we have steam exiting the core and in the hot legs, going up into the steam generator tubes and then flowing back the upside and down the downside, both those routes, and returning to the vessel.

So, you can see that the code calculation is giving the right overall behavior, although quantitatively it's somewhat off.

MR. WULFF: Why was the calculation started at a higher value than the test?

MR. JOHNSEN: The single-phase natural circulation condition was not precisely matched. I don't exactly know why, but it was not exactly matched. It's off somewhat. It could be the imprecision in the steam generator heat transfer loss coefficients around the loop. I'm not certain.

Now, in the calculations, of course, we can look at velocities that are being calculated in the hot leg, whereas of course, in the test, these were not measured, but this part here shows, again, as a function of the inventory in the system, the liquid and vapor velocities of the code was calculated in the hot leg.

As you can see, they start out with co-current flow through the period where two-phase natural circulation occurs, and then eventually, the liquid velocity was negative, and the vapor velocity remains positive. This is the reflux mode of natural circulation.

So, this shows that -- I think it illustrates that not only theoretically can the code do it, but it also matches some experimental data, and that's the extent of that.

MR. DAVIS: Excuse me, Gary. Just for clarification, the first problem you showed us is identical to the one that's in Volume 3, Section 218.

MR. JOHNSEN: That's correct.

MR. DAVIS: And in there, it also shows MOD2 results, which are identical to MOD3.

MR. JOHNSEN: I don't know if they are identical, but they are certainly close.

MR. DAVIS: Yes, just about an overlay. So, there wasn't really anything done to MOD3 that improved the countercurrent flow.

MR. JOHNSEN: Well, the off-take model that I mentioned a moment ago in answer to Ivan's question was new in MOD3.

MR. DAVIS: Okay.

MR. CATTON: And I guess, in MOD3, you go back and ask what is the liquid level.

MR. JOHNSEN: You go back and ask -- because it becomes important for dowering out an off-take. So, that was new in MOD3.E

MR. ZUBER: The problem then comes when you have really high-velocity flows. The velocities here are really small. So, essentially they don't contribute anything to the movement of the liquid.

MR. CATTON: The liquid surface was flat and shiny, and you could have used the fishing-pole method for measuring velocity, it was so nice. Do you know what that is?

You drop a line in, and you've got a flow. The distance of the rings from the line on both sides is related to the velocity.

MR. JOHNSEN: The rings that are coming off the string at the surface.

MR. CATTON: That's right. You can use that as a very accurate measurement of the flow velocity.

MR. DAVIS: Put that model in RELAP.

MR. BEELMAN: Is this a homework problem?

MR. SCHROCK: Before you turn that off, I didn't understand how you judge anything about the code capability from this. Why don't you compare this with data?

MR. JOHNSEN: There is no measurement made or attempt made at trying to measure the individual phase velocities in the hot leg. There is no meter in there that's sitting on the top of the pipe to measure the vapor.

MR. SCHROCK: What is this conveying to us? I missed the point.

MR. JOHNSEN: It's another demonstration of a situation where you have horizontal flow with countercurrent, liquid flowing one way, vapor flowing the other, positive velocity on the vapor toward the steam generator, negative velocity on the liquid heading back toward the vessel.

MR. SCHROCK: So, it demonstrates that, yes, you can alculate it, but you don't have evidence of how accurate it is.

MR. JOHNSEN: We have no evidence of how accurate it is, other than this sort of corroborates the overall behavior is being calculated properly.

MR. CATTON: You're not being fair to yourself. You do have evidence, because some of these calculations were done a long time ago, when you did your SEMISCALE reflux.

MR. JOHNSEN: Yes.

MR. CATTON: And at that time, the results compared very well.

MR. JOHNSEN: Thank you.

MR. CATTON: Actually, those results compared very well.

MR. JOHNSEN: There's one limitation in what I've said so far, and that is -- the Japanese pointed this out to us, by the way -- is that the code will not calculate a hydraulic jump if one were to occur.

MR. CATTON: I understand that. That's why, at the bottom of this, where the hot leg tips to go into the vessel or into the steam generator, when the angle change takes place, you could have a hydraulic jump, and you're going to miss that.

It seems to me you could go back in and do that by hand as to whether or not you've got a hydraulic curve.

MR. JOHNSEN: Super-critical to sub-critical flow. But we've sort of assumed that whether or not we can predict a hydraulic jump probably isn't all that important.

MR. CATTON: Have you tried to decide whether or not the heat transfer is important?

MR. JOHNSEN: Yes, and really, the answer is facility-dependent.

MR. CATTON: I'm referring to AP600.

MR. JOHNSEN: We have not looked at that, have we, Ron?

MR. BEELMAN: Yes.

MR. JOHNSEN: We have?

MR. CATTON: I couldn't hear you. What's the answer? Yes, it's important?

MR. BEELMAN: It is important. During the phase of LOFT when we got into small-break LOCA experiments, we decided then that the heat structures were important to the calculation of pressure, most notably, the energy transfer.

So, all of the heat structures in the piping systems, on the PSIS lines, the vessels, all of that stuff is modeled in the input model.

MR. JOHNSEN: Let me ask you a question. Have we even run a calculation on AP600 where we have compare two calculations, one with and one without heat structures in the pipes?

MR. BEELMAN: There is no reason to go back. We learned that lesson in LOFT.

MR. JOHNSEN: But LOFT is a small-scale facility.

MR. BEELMAN: I don't care.

MR. JOHNSEN: It doesn't have 31-inch pipes.

MR. CATTON: What I'm trying to decide is whether or not the poor heat transfer in the stratified flow model can be accepted, and I'm not getting answer to that question.

MR. BEELMAN: It's something that needs to be fixed.

MR. CATTON: That sounds fair enough.

MR. BEELMAN: But I don't speak for the code developers.

MR. CATTON: I don't either.

MR. JOHNSEN: Well, I'd have to know that it was important before I worried about it.

MR. CATTON: Well, that's what I'd like to know, and if it is important --

MR. JOHNSEN: I don't know if we know that. I don't think we know that.

MR. BEELMAN: There are going to be long periods of time --

MR. CATTON: Does he speak for you?

MR. JOHNSEN: He never speaks for me.

MR. BEELMAN: Nor vice versa.

MR. CATTON: Does that mean it's going to be checked?

MR. WAGNER: I have a question on what you're really recommending, because you have to vary the heat transfer.

MR. CATTON: At this point, I am not recommending anything. I made an observation. The observation is that, when you have stratified countercurrent flow, the heat transfer could be a little bit screwed up, whether it's boiling or condensation, okay?

If the heat transfer is not important, then I guess, emotionally, I care a lot, but from a practical point of view, I guess I could accept the rationale that's been used in the past.

On the other hand, if the heat transfer is important, then I think I'm very concerned.

MR. WAGNER: What I'm leading up to is the heat conduction is a one-dimensional representation. We'd probably have to then do 180 degrees worth of a two-dimensional calculation on the heat conduction, too, and that's a big jump in the calculation.

MR. CATTON: But you see, if it's important, you're going to have to figure out a way to deal with it, and what I'd like to know is is it important, and it looks like we don't have that answer at this point.

MR. JCHNSEN: I'll discuss, I guess, with my customer if he wants to allocate resources to take a look at that.

MR. CATTON: We'll pursue this with Westinghouse, I'm sure.

MR. JOHNSEN: Thank you.

MR. CATTON: Thank you.

MR. ZUBER: It's not important.

MR. CATTON: You don't think it's important. I would really appreciate a little help on this.

MR. SHOTKIN: One further question. All of the calculations are done with heat slabs in the pipes. If the pipes are hot, there is heat transfer to the fluid. I am not questioning that, whether or not there should be heat slabs.

Your question is, given the heat slabs, then the heat is transferred properly into the different phases. Is that your concern?

MR. CATTON: Well, I think maybe you're complicating the question. The way you treat the heat transfer now will not address the countercurrent flow correctly.

MR. SCHROCK: Among other things.

MR. CATTON: Among other things, but it won't calculate it correctly.

So, the question is is the heat transfer important? If the answer is no, then this gets dropped. If the answer is yes, then we should do something.

MR. SHOTKIN: We're not worried about co-current flow, just countercurrent.

MR. CATTON: I'm worried about all flow, Lou. You know that. In long transients, my recollection from SEMISCALE is that you get this highly-stratified flow, with the liquid running one way or maybe even both going the same direction, but it's stratified flow.

MR. SHOTKIN: I understand. I understand.

MR. BEELMAN: But we do that presently in vertical stratified flow. You should be aware that, if there is a level in a cell with the heat structure --

MR. CATTON: Yes, that's different, and I understand that.

MR. BEELMAN: If I understand what you're asking us, all you're asking is that the heat transfer to the vapor phase be apportioned over the surface area that's exposed to the vapor phase.

MR. CATTON: More than that. See, the heat transfer coefficient to the vapor, if it's condensing, is very high --

MR. BEELMAN: Yes.

MR. CATTON: -- and it's very low to the liquid.

MR. BEELMAN: Yes.

MR. CATTON: If I'm boiling, it's the reverse, and this is not a part of what you do.

MR. BEELMAN: Right. It should be in the correct regime, but all you want to do is apportion the contact area over the two phases.

MR. CATTON: And the magnitude of the heat transfer.

MR. BEELMAN: Yes. I think we understand your suggestion.

MR. CATTON: Well, first it's a question. Is it important? And I suspect that, in these long transients, it well could be.

MR. BEELMAN: That will be one of the sensitivities we will look at.

MR. CATTON: Okay.

MR. ZUBER: How can you do a sensitivity if your models are inadequate?

MR. BEELMAN: There are nodalization remedies for this.

MR. CATTON: What they'll do to test the sensitivity is they'll make two pipes, and they'll let the vapor flow in one and the liquid in the other.

MR. ZUBER: And then what?

MR. CATTON: Then the vapor can be condensed rapidly. It's not very good, because the apportioning of the area is not necessarily right, but it certainly will tell them whether or not it's important.

MR. BEELMAN: It tells us whether or not the magnitude will be a factor.

MR. CATTON: That's right.

Next we have Mike Modro, testing and modeling of steam generator tube rupture.

I take it, Mike, that you mean one plus, just one. I thought the big question was when there was multiple tube ruptures.

MR. MODRO: This would be a system effect. Here we are addressing the issue of experimental modeling of the tube rupture.

MR. CATTON: Didn't NRR ask about the multiple tube rupture, that that was where the concerns lie?

MR. MODRO: Yes.

MR. SHOTKIN: This is in response to a question.

MR. MODRO: The issue is how do we model in experimental facilities a steam generator tube rupture, but first, what is really the issue, how a steam generator tube rupture can look in a power plant.

There are two possibilities, really, one somewhere on the top of the U-tubes, which is usually a vibration-induced tube rupture, and more common, tube ruptures at the bottom of the tubes close to the tube sheet, and this would be really induced by corrosion.

MR. SCHROCK: Could you not have it broken on the other side, though?

MR. MODRO: On any side.

MR. SCHROCK: Yes. So, there's three different situations.

MR. MODRO: Yes. It can be on both sides.

MR. SCHROCK: The point that I was making before is not the same when the break is where you've shown it as when it's close to the tube sheet on the hot side. Those situations would be different.

MR. MODRO: A different flow, yes.

MR. SCHROCK: Right. Okay.

MR. MODRO: This may be more severe in terms of that you are getting a lot of cold fluid out here.

MR. SCHROCK: Could be.

MR. MODRO: But how it is modeled in facilities, in facilities like ROSA or SEMISCALE, it was modeled using a separate tube which is connecting the steam generator with the secondary side.

MR. SCHROCK: Could I ask a question related to the previous slide, because in looking ahead, I see you don't address it.

The point that I made yesterday, that RELAP5 does not have a model for flashing flow in pipes is underscored in looking at your previous view-graph. Could you show the previous view-graph?

MR. MODRO: Yes.

MR. SCHROCK: Okay. The point that I'm making here is that I do not think that RELAP5 has a model to calculate the break flow from the hot plenum through that tube.

MR. JOHNSEN: Virgil, I didn't properly respond to that issue yesterday, and we would contend that the critical flow model in RELAP is not a nozzle-only critical flow model.

MR. SCHROCK: Well, you'd have to show how that's the case, then, because the results that you described in the documentation say that it is a nozzle model, and indeed, when you use the relationship in order to get the de-pressurization of the flow approaching the critical state, the only way you will have that de-pressurization is when you have area change.

You don't have it in the tube except by friction, and that creates a different situation, in which you do not have it occurring close to the critical section.

MR. JOHNSEN: It does extrapolate from the cell center to the edge whether or not there is an area reduction. Let me say this. If we have time this morning, I guess I'd ask that --

MR. SCHROCK: What you're arguing, Gary, is just fundamentally incorrect. The fact is that the phenomena are different for the flashing in the pipe. Flashing occurs someplace back in this tube, and then you have a two-phase problem approaching criticality at the end of the tube.

MR. JOHNSEN: That's right.

MR. SCHROCK: And there is not a model in RELAP5 to deal with that as it's described in this manual.

MR. JOHNSEN: The tube would be nodalized, and the flow would flash on its way to the exit.

MR. SCHROCK: And what do you use as a flashing criterion?

MR. JOHNSEN: That's inherent in the code whether you're flashing down a pipe or you're flashing during de-pressurization.

Let me make another point.

MR. SCHROCK: Have you assessed it?

MR. JOHNSEN: Yes. Marviken --

MR. SCHROCK: Have you assessed it for this situation? Marviken doesn't have long pipes.

MR. JOHNSEN: It does at the exit of some of the configurations. It does, and we have assessed the code with that data. So, I'd like to come back to that with someone who is more knowledgeable than I am about it if we have time.

MR. SCHROCK: Well, I don't think you will be able to do it in this meeting, but if, in fact, it addresses this problem, it should be described in the documentation how it addresses this problem. I don't believe that it does that.

MR. JOHNSEN: It may very well be that the documentation is inadequate.

MR. CATTON: If it got left out, you certainly should include it and put this to rest.

MR. JOHNSEN: Agreed.

MR. SHERON: Is it a safety problem? I haven't heard that this is a safety problem. It's a nice academic problem, but I'm trying to figure out what is the safety problem.

MR. SCHROCK: No, no, no, Brian. The correct evaluation of the break flow cannot help but be a safety problem.

MR. SHERON: Why? I said before you never know what the break size is.

MR. SCHROCK: You have many PIRT evaluations that consistently rank break flow as high. Now, how can you tell us that break flow is not a safety concern?

MR. SHERON: What is the safety concern? Is it risk? Is the core going to melt? I'm asking a question. I mean I don't know what the safety concern is here.

MR. SCHROCK: The fact is you don't know whether the core is going to melt because you don't know the evolution of the transient, because you have an incorrect computation.

MR. SHERON: I can't believe that if the break flow is a little bit higher than it should have been for a simple tube that I'm going to wind up with a melted core. I've got my safety systems. They're all going to work.

I'm trying to figure how much effort I'm supposed to put into this to address it, as opposed to working on the more important things that are needed for AP600.

That's why I'm really starting to get troubled, because I've heard a lot of problems, and I don't know -- everybody says, you know, you should fix this, you should fix this, you should put this on --

MR. CATTON: The steam generator tube rupture I thought was one of the prime concerns.

MR. SHERON: The only concern with the steam generator tube rupture was that, if you have multiple tube ruptures, it may be an accident which actuates the ADS in a passive system --

MR. CATTON: That's right.

MR. SHERON: -- while the system was at some high pressure, okay?

MR. CATTON: So, if you're going to determine whether or not it's going to actuate the system, you really should have a pretty good handle on the flow out of the tubes, because that what ties into the pressure.

MR. SHERON: For a given geometry of a break, okay? But like I said, when I have a tube rupture, I don't have a break flow meter in the control room that says it's a tube sheet break or a split of this size area.

MR. CATTON: I can give you an argument, Brian, and decide I don't need any codes.

MR. SHERON: From a risk standpoint, I would probably agree. I'm serious, okay?

I'm just trying to say that, you know, when I look at the resources I have and what I'm hearing about, you know, gee, you know, just because you don't have a model for this or you didn't describe it right, therefore, you know, go off and spend a lot of -- you know, I mean I have got to balance this, and I am not getting any guidance from the subcommittee.

MR. SCHROCK: What we're doing is giving you a technical opinion on the status of this code, and I think that's our responsibility, to state that clearly and as accurately as we can.

What I find, in reading this documentation, is that there is not a model for this class of critical flow problems. My belief is that there should be. The resource issue is not my problem. I don't know what the resource problem would be for you.

I find it incredible that we're at this point today talking about this problem after these years of dealing with --

MR. SHERON: I'm sorry. I hear Gary say that the code does, indeed, calculate this; it just may not be described in the manual.

MR. CATTON: Fine. Then fix it.

MR. SHERON: That's what I've heard, is it's always fine, let's fix it, okay?

MR. CATTON: No. If the documentation doesn't represent what's in the code, then the documentation should be changed to represent it.

MR. SHERON: There was not a complete write-up that may have explained it to the point where everyone understood it, okay?

MR. SCHROCK: Well, Brian, let's cut the crap on this, if I may say so. I am an expert in this subject, whether you like that or not, and what I am saying to you is that I do not think that there is a model for this which is credible in this code.

MR. SHERON: Okay.

MR. SCHROCK: Now, you can tell me there is a means by which this code attempts to calculate it. If there is, explain that, and don't tell me that that requires an explanation beyond the norm to the average technical community. You're talking to an expert on this subject.

MR. SHOTKIN: What I thought your concern was was not whether it's in the code or not. You're concerned whether the facilities are going to capture the flow coming from both directions.

MR. SCHROCK: What was what brought the subject up initially, and we haven't heard the resolution of that.

MR. CATTON: That's what he's going to do for us.

MR. SCHROCK: That's what he's going to do.

MR. SHOTKIN: Right.

MR. SCHROCK: And in order to do that, we need to know is his calculation of the break flow through this tube a credible calculation?

MR. SHOTKIN: We think it is, and maybe the documentation is wrong.

Now, we can fix that, but rather than come back to this another time, could we also resolve this experimental problem? That's what we'd like to do, is just show you how it's done experimentally.

MR. CATTON: Go for it.

MR. MODRO: Okay. Now you see how those two situations can look in reality. This configuration is modeled with an external tube connecting the primary side with the secondary side. This tube may be different in size, or it may be a bigger size.

It's clear that this type of arrangement will not give us a correct exact break flow, just simply because both ends, coming from the loop end and the end coming from the tube sheet, has the total area in this box here.

So, eventually, we will get a larger break flow than would be expected.

MR. CATTON: I'm sorry. I didn't understand when you first put this up. How you represent the break is you just tap directly into that lower plenum and dump it into the top.

MR. MODRO: Yes. It's a separate pipe.

MR. SCHROCK: So, this one has a flow which is different from either of the two flows shown in the other model.

MR. MODRO: Yes. It's like a double flow, basically, from that side.

MR. SCHROCK: The question is how does this flow compare with the sum of the other two?

MR. MODRO: We think it's conservative in terms of mass flow rate.

MR. CATTON: It gives you more flow.

MR. MODRO: It gives more mass flow.

MR. SCHROCK: Are you looking for a conservative result?

MR. MODRO: There's always a compromise in models. In fact, it would be impossible, basically, to build a test facility and configuration like this, particularly with multi tubes.

MR. SCHROCK: I'm not arguing with that. What I'm saying is that you need to understand what the relationship of your experimental configuration is to the actual configuration that would occur in that postulated accident in a plant.

MR. MODRO: In the actual code, in the calculations we do for the plant, it is modeled that way, representing this type of geometry. When we do run a calculation of the experiment, it's modeled that geometry. So, we don't superimpose the geometries.

You are right in the sense that the conclusions of the correctness are not straightforward, but the issue is what is the uncertainty, really, about that flow, because this is what we are mostly concerned about, this flow through that tube.

MR. SCHROCK: Okay. Well, you have the code that you say is capable of calculating all three of these flows.

MR. MODRO: Yes.

MR. SCHROCK: And now are you going to show us results of the calculation from each of those three geometries and relate them?

MR. MODRO: No, I don't have this data.

MR. SCHROCK: Then what is the basis of the argument that you're making?

MR. MODRO: Engineering judgement.

MR. SCHROCK: Well, I have difficulty accepting that engineering judgement unless you can show me a computational result. You have a code that will calculate each of those three situations. You intend this one to represent this situation over here.

That means that you have to know what the size of the pipe is. You have to know how the flow through that geometry is going to relate to the flow of these. You can't make an argument about it based on engineering judgement unless you've done the calculation.

MR. SHOTKIN: I agree with you that the tests do not replicate the steam generator tube rupture that would occur in the plant. The plant calculations will replicate that but will be assessed against data that doesn't.

You asked the question, does ROSA, on a steam generator tube rupture, know what's going to happen in the plant, and the answer is no.

Now, Mike has given you some estimate,

conservative or not, but I don't think that's the issue. We'll have to do what you say. We'll have to show how it behaves in the plant.

ROSA doesn't model it this way. SEMISCALE doesn't do it. No facility can.

MR. CATTON: How does SPES do it? Is it like this?

MR. MODRO: It cannot do it either, because it's even smaller.

MR. CATTON: What's even smaller?

MR. MODRO: SPES. So, it cannot do it.

MR. CATTON: I understand now why you can't do it this other way, because you're going to get holes that are too small. I didn't understand that at the outset. I can see that now.

In SPES, does it have the cold leg hooked up like you show here?

MR. MODRO: I think so, yes.

MR. CATTON: Even so, with it being that small, that's still going to be a pretty small pipe, isn't it?

MR. MODRO: Yes.

MR. CATTON: So, somehow that part of the scaling should be addressed for SPES. How do they decide how long or how many -- how diameters long should that tube be to get the proper kind of behavior?

MR. MODRO: We are awaiting the tests that should address the uncertainty associated with it.

MR. CATTON: And I guess you guys have to do the same thing for ROSA. We'll see that at some point, Lou?

MR. SHOTKIN: Sure. Yes.

MR. WULFF: Can I ask you, are you concerned that you might have two places of choking?

MR. MODRO: It is possible.

MR. CATTON: It won't stay choked.

MR. WULFF: It stays choked downstream of the valve, then you have choking inside a pipe, and that is quite different from the choking in the water-filled space on the right-hand side, and I am not sure how you connect the two by saying, in the end, that if I can simulate the choking downstream of the valve, I can also predict it correctly at the steam generator geometry.

MR. MODRO: I'm not saying that I can predict correctly. We really don't know where the choking will occur. This depends on the conditions in this volume, and it depends, naturally, on the geometry of this pipe.

We have seen in some tests that the choking plane may move, particularly in a complex geometry.

MR. CATTON: It also may oscillate back and forth between the valve and the exit plane.

MR. MODRO: Yes.

MR. CATTON: When the exit plane chokes, the pressure drop decreases. When the pressure ratio across the valve decreases and it un-chokes, then it's going to want to speed up and choke again.

MR. WULFF: My concern is that you get less flow in the experiment or could possibly get less flow in the experiment than in the full-size --

MR. SCHROCK: But Wolfgang, this is really what I was after in bringing this up, that the design of the experiment requires an understanding of the relationship among these three geometries involving critical flows, and in order to design this, just as Ivan was saying, the L over D and the diameter separately of this pipe in the experiment is going to have to be chosen in order to create a situation that's similar to this one that he shows in the other picture, in the actual steam tube rupture.

In order to do that, you need to make the calculations. It's completely a mystery to me why you're reluctant to do those calculations in support of the experimental design.

MR. CATTON: Well, I think Lou just said they're going to do it. So, I guess we're just going to wait and see.

MR. SCHROCK: Well, the experiments are already designed.

MR. MODRO: In preparation of the design, we have done a steam generator tube rupture calculation, as well, for AP600 and, as well, for ROSA with this type of geometry, but that's existent in ROSA.

MR. SHOTKIN: You've seen those calculations.

MR. MODRO: It's in the report you have on the ROSA calculations.

MR. SHOTKIN: I understand your concern, but I think that experimental pipe is much larger. We can check that. It's much bigger.

MR. SCHROCK: It depends on what valve you're using.

MR. CATTON: That's it? Thank you.

MR. MODRO: I think we went thoroughly through that, and basically, we will be continuing this work on that, but I wanted to stress that this type of approach makes the test possible, and the point of Professor Schrock is well taken.

One has to compare the calculations and also the modeling of the actual geometry in determining the input itself.

MR. CATTON: My recollection from the CSAU for LOCA was that the L over D played a role in the break.

MR. MODRO: Yes.

MR. CATTON: I just don't know the details.

MR. SHOTKIN: I was just told that, in ROSA, the pipe goes up -- can handle up to 10 tubes. So, it's a large pipe, and it goes not into a valve but into an orifice. So, the break is through the orifice.

MR. DAVIS: Mike, where did the last two lines on that slide go?

MR. MODRO: Just cross them out. Sorry.

I think I am still next on the list.

The first components were discussed in previous presentations. So, I will only talk about those remaining four components.

ADS is basically a standard set of volumes and valves, but we don't have any detailed data currently on how those physically are arranged. Therefore, we don't have any model, particular model which could be discussed at present.

On the previous slides, I showed you the ADS arrangement. This is currently treated, as you can see here in this figure, for the first three stages and for the fourth stage.

We expect to receive enough detailed information to start modeling this. The usual approach is standard RELAP5 control volumes and components of the valves.

Additionally to this, we know that there is a sparger, and it was also mentioned in the previous presentation about the sparger modeling. So, there are --

we will evaluate, eventually, if there is a need for a new sparger model.

MR. ZUBER: This is the 481?

MR. MODRO: Pardon me?

MR. ZUBER: Where is the 481?

MR. WULFF: 481 goes into the IRWST.

MR. MODRO: Yes. This goes to the IRWST. These two are going directly to the containment. It's really a standard approach. We don't expect any problems.

The steam generator -- there are not big differences between the current generation of steam generators and this steam generator which will be introduced into the AP600.

So, the issue is only how long the tubes are, to identify it and model it according to the same principles as we have been modeling steam generators for the current generation of reactors.

We use currently, for the plena of the steam generator, single volumes and connect to those single volumes the two pumps and the U-tubes.

We expect a complete mixing result within these plena, and the code treats this currently as a solution which is shown on the next slide, where there are velocities, average velocities determined for the volumes and then fed into the momentum equations for the individual junctions.

If the analysis and review of the calculation would indicate some problems which would lead to a conclusion that there is a stratification occurring in the plena, we will go and do some sensitivity calculations by nodalizing the plena.

MR. CATTON: Now, how are you going to -- by stratification, you mean separation.

MR. MODRO: Separation, yes.

MR. CATTON: In that complicated geometry, how are you going to decide -- I mean I understand how can use the Taitel-Dukler maps in other areas, but here this is a completely different geometry, and you have funny angles, all sorts of things.

MR. MODRO: It will be a vertical stratification problem, not a horizontal stratification problem.

MR. CATTON: Isn't that on the same level?

MR. MODRO: They are.

MR. CATTON: It seems to me that if both those pipes are stratified --

MR. MODRO: This component is six feet tall.

MR. CATTON: Okay.

MR. MODRO: So, we would expect to have the formation of a level which drops down.

MR. CATTON: Okay. So, as long as it doesn't drop down below the top of the cold legs, then it's --

MR. MODRO: Yes. If it drops down below the cold leg, it should be addressed.

MR. CATTON: Now, when I look at this J-1, J-2, J-3, which one is which? Are J-2 and J-3 the cold legs and J-1 the tubes in the steam generator?

MR. MODRO: Yes. This will be done with the U-tubes. It's a generic solution.

MR. CATTON: I understand.

MR. SCHROCK: It's one, though, that was developed more for pipes with branches in the pipes instead of plena.

MR. MODRO: Yes.

MR. SCHROCK: Plenum is a different situation. the V-1 in your plenum is nearly zero.

MR. MODRO: Yes. There is more velocity there.

MR. SCHROCK: It makes me wonder if the method is at all applicable to the plenum case.

MR. CATTON: Virgil, on the other ones, does the momentum cross the junction in the flow from J-1 from J-2?

MR. JOHNSEN: Yes.

MR. CATTON: It does?

MR. JOHNSEN: I think so.

MR. CATTON: Then here I guess Virgil is right. It should probably be a different kind of a junction, more like a reservoir.

MR. MODRO: It can be then turned around, and we can use closer junctions instead, which are not carrying the momentum.

MR. JOHNSEN: You're saying that the velocities exiting the tubes would be very, very long? Is that what you're saying?

MR. SCHROCK: No. The velocity, V-1, which is your -- it's practically zero. In an ordinary branch problem, that's never the case. It's more like J-1.

MR. JOHNSEN: But the fact that the flow area is very large and therefore the velocities are low are accounted for in the equation. So, if it comes to a stagnation point, that's recognized in the code.

MR. SCHROCK: Okay. I was misinterpreting what you're doing with that V-1. You're not describing that as the velocity in the node. That means the volume. V-1, though, is a very small number. How do you say, then, that that's in the equation?

Maybe if you tell me what the VV-1 means, I'll understand better what you're saying.

MR. RIEMKE: VV-1 is the volume velocity in cell V-1.

MR. SCHROCK: And the cell V-1 is the whole plenum.

MR. RIEMKE: That's the whole plenum. On the left side is junction J-1, and on the right side, there are two junctions, J-2 and J-3. The way we calculate the volume velocity is that first equation.

We take half of some kind of average of all the junction velocities coming in the left. In this case, there's only one.

So, we call that VV-1, in. That's what the second equation says. That's the VJ-1.

The last equation is where we're going to take kind of an average of all the junction velocities going out. We call it V-1, out. So, we kind of average -- we take half of all the velocities that are inside and half of all the velocities --

MR. SCHROCK: What do you do with the V-1 after you're found it from the top equation?

MR. RIEMKE: Right. And that's what that first sentence says. That volume velocity will then be used in the momentum flux term for all the junction velocities that are connected to that volume. So, that's junctions J-1, J-2 --

MR. SCHROCK: So, then I don't agree that that's right.

MR. CATTON: There's no momentum involved in this.

MR. SCHROCK: I guess I go back to my original position. I don't think it's assessing the momentum flux at any of those flows on the boundaries of this V-1.

MR. WULFF: If you already have the velocities, why go through this, and the second question is how do you ever set up a momentum balance unless you know what the forces are exerted from the walls on the fluid?

MR. JOHNSEN: That's a one-dimensional approximation.

MR. WULFF: If you started out with what you already have, you wouldn't need any of this.

MR. JOHNSEN: It's one-dimensional.

MR. RIEMKE: One-dimensional.

MR. JOHNSEN: It's a one-dimensional code.

MR. MODRO: Okay.

The next item on the list was the pressurizer. We have to do some nodalization sensitivity studies to see how the mixture is treated this pressurizer during the ADS operation.

The most exciting was the nodalization of the downcomer. As I mentioned yesterday, we cannot do much in AP600 because of the two cold legs in the downcomer on each loop and the direct vessel injection and the complex flow associated with the injection.

So, it's very important to calculate the appropriate temperature through the downcomer and what is fed into the cold leg. We have been doing several sensitivity studies.

MR. CATTON: This nodalization scheme for RELAP5?

MR. MODRO: Yes. It's in RELAP5.

MR. CATTON: Back when McGwire was being licensed, this same approach was taken, and it's very non-physical, and you can actually show when and when you cannot use this particular type of approach.

MR. MODRO: We are bench-marking this approach using COMMIX.

MR. CATTON: You have to be very careful. If you shift the nodalization structure, everything shifts.

It turns out, for acoustics, this is an excellent method, but this is where it was developed, and I guess Stan Fabic was one of the ones who developed it, who worked on this. It's inappropriate for this application.

MR. MODRO: It's the only way, however, to show the flow distribution.

MR. CATTON: And it served its purpose for McGwire. It showed that water got into the lower plenum, although if you looked at the velocities that were higher up, they were ridiculously high.

Now, there were several people that got involved in this -- I don't remember when McGwire was licensed, but whenever it was licensed -- and at that time it was RELAP4. This part of the problem is still the same. I think you need to do something else.

MR. MODRO: This is why we are using COMMIX to check, to benchmark this flow.

MR. CATTON: You have to be careful with COMMIX, too. You could use it and then develop a transfer function that you incorporate into RELAP5. That would probably be a reasonable thing to do, or else build a simple two-dimensional part of RELAP5. I understand you have that.

MR. JOHNSEN: What's that?

MR. CATTON: I understand you have the two-dimensional RELAP5 somewhere else. At least I've seen reference to it.

MR. JOHNSEN: Yes, we do.

MR. CATTON: EG&G East?

MR. JOHNSEN: Yes.

MR. CATTON: Where are the reports? I haven't seen what you've done.

MR. JOHNSEN: That was work done for Savannah River.

MR. CATTON: The conclusion that was reached at the time of McGwire by some of us was that you could not use that.

MR. MODRO: This is for -- basically for small-break type of issues.

MR. CATTON: It may not matter, I don't know, but

I think it deserves a little attention before you just blindly go forward, because people did look at this and did conclude that it shouldn't be used. I didn't know COMMIX could handle two-phase flow.

MR. MODRO: This is for the single-phase flow, basically. We don't have that much of the issue later when the level will drop below. Where it is a problem is the early part of the transient.

MR. CATTON: This is single-phase.

MR. MODRO: You have the cold water coming in here and the hot water coming in here. You have a very complex flow pattern.

MR. CATTON: It turned out that if you wanted to do it, you could take the proper ratio of the horizontal to the vertical and then there's some strange kind of an angle that, if you used it, seemed to do things okay. It's not a trivial problem to show that it's okay to do that.

MR. MODRO: Definitely not.

MR. SCHROCK: You have the additional problem of the resistance in the horizontal plane between nodes such as 104 and 105, etcetera, circumferentially. What do you do for that?

MR. MODRO: You can still introduce this into the junctions.

MR. BEELMAN: Mike, let me help you out here.

MR. MODRO: Go ahead.

MR. BEELMAN: We realize that there is no transverse momentum in a cross-flow. So, what we have done in the cross-flow junctions is based upon the velocities that we think we're going to be seeing.

We have put a form loss there, at all the cross-flow junctions, of .07 to account for the wall friction which is not accounted for in the transverse direction of the 1-D code and to account for whatever curvature is in the downcomer.

MR. CATTON: So, you're not doing just a straight pipe network.

MR. MODRO: No, no.

MR. BEELMAN: It's important to see that the situation will steady out and stay at zero flow. That's very important.

We didn't want the nodalization itself, due to numerical inconsistencies or glitches, to reduce flow in the downcomer, and in order to damp those things out, what we did is we looked at the wall friction term that should be there, we looked at the curvature of the wall, and we came up with a number that did settle the thing out, which is also reflective of the actual wall friction and curvature.

MR. SCHROCK: What wall friction are you trying to match?

MR. BEELMAN: The transverse wall friction, the distance from the cell center of one node to the cell center of another at the same elevation.

MR. SCHROCK: That's clear, but what I'm asking you is what is the formulation of that wall friction? How do you know that wall friction?

MR. BEELMAN: I know the roughness of the wall, and I just go to standard correlations and come up with a loss. That's all I could do.

MR. SCHROCK: What standard correlations, like fully developed flow in a pipe?

MR. BEELMAN: No. All we used is an approximation. That's all we used. That's the best we could do. To use otherwise would infer that we need to use a fully-developed 2-D thing, because you get momentum transfer.

MR. SCHROCK: Well, that implies that you have a parabolic distribution of velocity in the radial direction, which you do not have. So, that is why I asked the question.

It's not as simple as you portray it. I mean you don't have a good handle on what the friction effect is here.

MR. BEELMAN: You're right, Virgil. We had to do something to reconcile this nodalization which we think is needed in a 1-D code. We do what we can with what we have.

MR. SCHROCK: I understand what your objective is, and I am not arguing with that objective.

I'm saying, within that objective, you have the additional problem of coming up with a reasonable assessment of what the frictional effect is for circumferential flow in an annulus, and if you're using the presumption that it's a parabolic velocity distribution in that annulus, it's not right.

MR. DAVIS: I have a question, Mike. We haven't heard anything about modeling in the core. Are there any design-basis accidents for AP600 in which heat transfer becomes an important consideration?

MR. MODRO: Not really. The heat flux here is a little bit different, because we open all the ADS's, so we have a very high-velocity flow through the core. So, the core is usually kept pretty cool, and there is a lot of entrainment and so forth.

We haven't yet modeled in much detail the core itself. We have seen, in the general scheme, there is only basically one stack of volumes.

In the new approach, we are going to model three zones, basically, and several nodes. This will represent better the power distribution and also phenomena which may occur later in transients.

MR. DAVIS: Okay. So, I think what you're telling me is that the heat transfer problems that are identified in Volume 3 probably won't be an issue for ADS. Thank you.

MR. CATTON: Are you going to tell us about the pressurizer, or you've already done that?

MR. MODRO: I've done that.

MR. CATTON: Actually, we've gotten a bit ahead. We decided that we're going to delete VI and VII, but now I think we can put them back in, and Dave is just itching to get up here. You have one hour and 10 minutes.

MR. BASSETTE: I'll give you a summary of where we stand on ROSA-IV in SBWR facilities.

The recent events since the last time we discussed ROSA is that we got authorization to proceed from the Commission on August 11th. We signed a non-disclosure agreement with the contractor August 26th. We sent out the proposal, the RFP, on September 1st.

We had a meeting at JAERI in early September to clarify the proposal between us and JAERI and SHI. As a result of that meeting, we made some modifications. We sent those modifications out September 24th. We signed our letter of agreement with JAERI in October.

We received the proposal, the reply to our RFP, from SHI on November 4th, and we signed an initial letter contract to proceed with Task 1, which is the design phase, in late November.

We published the Idaho report on the comparison of our modified ROSA design with AP600 in December, then a second meeting with SHI that I guess Novak attended in February to finalize on the contract, and we have one last meeting in Tokyo the week after next, and we're expecting to sign the final contract at the end of March.

We have a resident engineer from Idaho due to arrive at JAERI in April.

The schedule calls for the modifications to ROSA to be completed by the end of this year, and there is a JAERI commitment to run three tests for us by this time next year, and we would expect to run additional tests during 1994, and this is a date we're working toward trying to get the information and a schedule compatible with when the SER is due to the Commission.

MR. ZUBER: I didn't mention it at the meeting, but my concern was and is that the first test to be run at this facility -- we don't have shake-down tests.

MR. BASSETTE: I'll cover that. I'm going to cover our shake-down tests. We have a proposal for a series of shake-down tests that I'm going to present to you, and that will be run before we start our actual testing.

The December date includes -- SHI, as part of the contract, has an obligation to run some characterization or shake-down tests for us. So, when I say -- that December date includes that kind of testing.

MR. CATTON: One of the things I think that I found very interesting in this meeting -- that's the CMT and how it couples into the rest of the system. It seems to me that's really crucial as far as the ability of the codes to work.

If what Ron says is right, then the impact on the codes is a lot less.

MR. BASSETTE: We have a CMT circulation test on the list.

MR. CATTON: Have you taken some pains to make sure that the top part of the CMT, the coupling to the pressurizer and the coupling to the cold leg, are done the way Westinghouse designed it?

MR. BASSETTE: Yes.

MR. CATTON: That's very important.

MR. BASSETTE: Yes. It's the same, the junction where the pressurizer pressure balance line comes in to the cold leg pressure balance line and the connection to the top of the CMT.

MR. CATTON: And you have a steam trap and all that kind of stuff?

MR. BASSETTE: We did away with the steam trap, because it didn't seem to be too important to us. That volume is quite small. The effect is very transient. You are dealing with just a small amount of liquid or steam.

MR. CATTON: And you're going to have to cook the test a little while before you start it so that you get the same kind of upper conditions that you would have in the AP600.

MR. BASSETTE: Yes. We have heaters on those lines so we can establish initial conditions.

MR. BEELMAN: It seems to me that all that's required here is, before you actually enter the test, that you fulfill the initial conditions that the test is supposed to begin from. That's all.

MR. CATTON: Yes, but I want to be sure that you know what Westinghouse is going to do, so that you can do that, and then, if part of your initialization is based on computation, I'd like to be sure that the computations are based on something that's meaningful.

MR. BEELMAN: I do not think the initialization of the test is based on a computation. I think I know what the temperature and pressure in that upper head of the CMT is.

MR. SCHROCK: In listening to Westinghouse's descriptions of their system on various occasions, I never heard the terminology that you've implied, "upper header," and I don't understand the distinction between a connection of pipes and a header.

A header usually means a large volume, a sort of plenum.

MR. BASSETTE: I think that "header" is kind of a misnomer here.

MR. SCHROCK: I wonder if maybe our thinking on it isn't being colored a little bit by stressing this terminology, "header." What is the volume of the region that we're talking about? What is the volume of the steam trap which you've eliminated from the ROSA-IV system?

These are questions, I think, that ought to be answered.

MR. BASSETTE: In the plant, the distance between the connection where the two pressure balance lines come together and the top of the CMT is like a foot or two, two feet, something like that.

MR. SCHROCK: Of what diameter?

MR. BASSETTE: It's a eight-inch 160 pipe. So, it's about six-and-a-half inches.

MR. SCHROCK: Six-and-a-half inches.

MR. BASSETTE: Yes, times two.

MR. SCHROCK: That's hardly a header.

Now, what is the trap?

MR. BASSETTE: The trap is something about this size. It's a small line just to collect any condensate.

MR. SCHROCK: It's not really a trap at all?

MR. BASSETTE: It's a condensate drain that brings that condensate back to the cold leg.

MR. SCHROCK: What is the steam trap? Can you describe it?

MR. BASSETTE: The trap is there to ensure that the pressurizer pressure balance line remains steam-filled as opposed liquid-filled.

The only reason that I've heard that it's there is that somebody at Westinghouse thought that this might reduce the potential for water hammer in this line.

MR. CATTON: So, they want to make sure they've got no condensate in the bottom of it.

MR. BASSETTE: Yes. They want to try to avoid the potential for water hammer.

MR. SCHROCK: And it's connected to the bottom of the eight-inch pipe?

MR. BASSETTE: Yes.

MR. SCHROCK: How big is that?

MR. BEELMAN: It's a one-inch line.

MR. CATTON: On any of your seven tests, are you going to run one with the CMT not completely full?

MR. BASSETTE: Not planning on it. You mean initial conditions?

MR. DHIR: Westinghouse is going to do that.

MR. CATTON: Oh, Westinghouse is going to do that.

Okay. When is Westinghouse going to run it?

MR. DHIR: Summer.

MR. CATTON: This coming summer?

MR. BASSETTE: So, this is basically how we scaled the new components. We maintained full height, full elevation for the new components and tried to match the -- preserve pressure drops between ROSA and AP600 and preserve individual component volumes.

This is the schedule for modifying ROSA. We're in the middle of the design phase and beginning a procurement fabrication phase. You see the modifications to the existing structures.

The IRWST, in particular, is a rather large new structure. It's elevated about two or three stories off the ground, and it holds about 45 tons of water.

As you can see, everything is due to be completed by the end of December.

MR. DHIR: I read the report which INEL did for SHI and JAERI with respect to scaling of pipes and so forth and also instrumentation. I thought it was a good report. However, I have two difficulties with that report.

One was there was no mention as to what the loss factors should be. Maybe Westinghouse has not provided it as yet.

MR. BASSETTE: No mention of what?

MR. DHIR: The loss factors.

MR. BASSETTE: Loss factors?

MR. DHIR: Yes. There was no numbers there. So, I don't know how SHI or JAERI will be able to size their lines and so forth.

MR. BASSETTE: Well, we had a total loss factor for each line in there.

MR. ORTIS: Marcos Ortis, INEL.

We don't have from Westinghouse all the details on those factors. What we have done for this -- many of those pipes that we suspect will have a loss factor, we have made provisions for an orifice. So, like Westinghouse, they will put an orifice, we will too.

MR. BASSETTE: Our objective was to choose lower flow resistances than what we understand -- what our information is and to match exact flow resistance using an orifice when the time comes.

MR. DHIR: I like the instrumentation, how much you are providing. It is better than even what Westinghouse is doing. However, I did not see any specification with respect to time constants for the instruments. What do you expect them to be?

MR. BASSETTE: I don't think it's in your version of the design requirements, but we have a table of measurement ranges and time constants and thermocouples.

MR. ORTIS: We've been giving them ranges, and specifically for the thermocouples, we gave them a time response requirement which they meet by far.

MR. DHIR: This is time constants for thermocouples, also uncertainties in flow meters and so forth. All those should be listed somehow, and somebody should go over it. I didn't see that in your report.

MR. ORTIS: Well, we haven't given them some of those, and they are supposed to tell us the instrumentation they are proposing.

Like we said we want a DP at this location. Then they will tell us what instrument they're going to put in and what uncertainty will that instrument have.

MR. CATTON: So, you haven't told them beforehand what uncertainty.

MR. ORTIS: No. We have discussed that we want it to be accurate.

MR. DHIR: But you should have some idea as to what you expect if they come back and say that the flow meter is plus or minus 30 percent.

MR. ORTIS: Well, we've talked about that verbally. They know that we want it to be reasonably accurate, and we have thrown out numbers verbally, and they know what we're talking about.

If we limit them by the accuracy that we request, then we may end up with a prohibitively expensive instrument.

MR. CATTON: But if you need it, you should say it.

MR. ORTIS: We have, as I said, in our discussions with them, talked to them about that. In fact, they are supposed to use those instruments to calculate -- to measure their own calculations of the pressure loss for pipes, and we have given them a range on those.

So, it is not spelled out, but we have talked about it.

MR. CATTON: We're going to have a more lengthy meeting on this. I think, at that time, we'd like to hear some of these numbers.

MR. BASSETTE: You can see there's about five or six weeks allowed for inspection and acceptance testing towards the end of the contract.

Then there's the list of equipment. The biggest -- aside from the IRWST, the biggest components are the core make-up tanks, and these are about two feet in diameter and 20 feet tall.

MR. WILKINS: This is the equipment that will be supplied by the NRC?

MR. BASSETTE: Yes.

MR. WILKINS: And shipped from the United States to Japan.

MR. BASSETTE: Well, it's all being fabricated in Japan by a Japanese company.

MR. WILKINS: Is that a company subcontracted to SHI or contracted to NRC?

MR. BASSETTE: We have our contract with SHI, and then SHI fabricated or procures some of the components themselves and some they purchase from other companies.

MR. ZUBER: Can you go back to that schedule, please? You say they will be doing the shake-downs.

MR. BASSETTE: Yes.

MR. ZUBER: And you will discuss basically what kind of shake-downs you will have?

MR. BASSETTE: I will spoil the suspense and get to that next.

Here's the acceptance tests. We do an as-built verification. We do a pressurization and leak-rate test. We verify operability and calibration.

We verify the operability of the valves and controls, and we verify the control logic, and you provide the volume versus elevation for the new components.

MR. ZUBER: These are really not shake-downs.

MR. BASSETTE: For all the new components, you do a drain test where you have a drain recirculation test. You do two of these, both the pressurizer pressure balance line and then the cold leg pressure balance line.

You do an accumulator blow-down, you do an IRWST injection, and you do a pressurizer drain, and then you do some hot tests, and these would include, let's say -- you try to do a -- you do a heat loss characterization where you bring the facility, you know, hot and then let's say you just turn everything off and try to isolate all the components from each other and just measure the temperature decay.

There would be a separate -- at least one or more, let's say, separate PRHR tests where you'd bring the facility to some steady-state condition and then just open the valves on the PRHR and measure the heat transfer, and you would do separate blow-downs where, again, you'd be at hot initial conditions and you'd open up an ADS stage one valve, measure the blow-down, and come back up, open up the ADS stage one and two valve.

Then we have the ADS valves. We've got three valves. One represents stage one. When we get to the stage two setting, we close that valve and open up a second valve which represents ADS stage one plus two, and again, we close that valve and open up the third valve, which represents ADS one plus two plus three.

So, we'd have four separate blow-downs exercising each of the ADS stages.

MR. ZUBER: And then you'll be taking data throughout the system to see how the system reacts?

MR. BASSETTE: Yes, take full system data, and then, from these, also it is intended to include a CMT recirculation test, where you'd bring the system to hot initial conditions and open the valves on the CMT, you know, a no-break test, and just watch the recirculation phase.

MR. CATTON: So, your ADS valves, you really don't have the stage one, stage two, stage three, stage four.

MR. BASSETTE: No. We decided to do it this way to avoid the complications of parallel flows.

MR. CATTON: You really can't track through the whole range of valves opening and so forth. You have to stage it.

MR. BASSETTE: What's the question? I don't understand.

MR. CATTON: If it's an actual accident in the plant, you're going to have stage one open and then stage two is going to open and then stage three and then stage four.

Here you have stage one, you have to shut it and get the other one open.

The thing is they don't have valve one, two, three, and four. They have a representation of one, a representation of one plus two, a representation of one plus two plus three.

So, by the time they have three stages open, they've had to shut the others, and that's going to be a rather complicated process to go from top to bottom through the transient.

MR. BASSETTE: See, another thing we're not representing is, in the plant, these valves open over a 30-second period or so.

MR. CATTON: So, you figure you can open up one and close down the other?

MR. BASSETTE: Well, we'd do it over a couple of seconds. We'd open up one and then close another.

MR. CATTON: You would have to make the decision then based on heat injunction thermocouple data coming out of the CMT.

MR. BASSETTE: We're actually going to use DP.

MR. CATTON: Automated?

MR. BASSETTE: Yes, it's going to be automated.

MR. CATTON: You're going to use DP?

MR. BASSETTE: Yes.

MR. CATTON: Not heat injunction?

MR. BASSETTE: That's right. We have included nozzles should we decide that we need to do heat injunction in the future, but right now we're using DP to actuate the ADS valves.

MR. SHOTKIN: What JAERI wants to put in their heated thermocouples, but Westinghouse is using DP, and we've talked with Westinghouse, and they said yes, you should use DP, also, because that's what we're using.

MR. BASSETTE: They still haven't finalized with their vendor.

MR. CATTON: This is not really ROSA-related, but who is testing the heat injunction thermocouples in an actual --

MR. SHOTKIN: You mean the Westinghouse one?

MR. CATTON: Yes.

MR. SHOTKIN: Ask Westinghouse.

MR. CATTON: I plan to.

MR. ORTIS: This heated thermocouple is not true. Westinghouse is not using heated thermocouples. They're using RTDs.

Heated thermocouples is what they say, but when we went and tried to use the same thing, we found out that what they're using is RTDs, and they haven't decided.

So, we're not using either. We're using the DPs.

MR. CATTON: Westinghouse is not using heat injunction thermocouples.

MR. ORTIS: No. They call it that way, but they're really RTDs.

MR. SCHROCK: They just don't know what a heat injunction thermocouple is maybe.

MR. ORTIS: I doubt that, but they use the same name, and it means different things.

MR. CATTON: Sure it does. If they're heat injunction, you can put a little power to it in order to get a more rapid response. If you don't put the power to it, then you've got to sort of wait until all the water drips off it or something.

MR. ORTIS: They have a very complex instrument, but we're not using either one. We're using DPs.

The other thing that I wanted to make clear is that, when we have the ADS valves, we simulate the valves with an orifice. The orifice is upstream of a valve that is much larger than the orifice, and that valve is the one that opens.

So, we can't simulate the slow opening of the valve, because we don't know how open it's going to be.

So, we just open the valve, and the orifice will simulate stages one, one-two, one-two-three.

So, that's the other clarification I wanted to make.

MR. WULFF: I have a question. Are you, in this second set of tests, measuring key delta-P's to get the impedances of pipes?

MR. BASSETTE: Yes.

MR. WULFF: It is not listed here.

MR. BASSETTE: Well, that's the purpose of the first four tests. I think, if you look at Westinghouse is doing in SPES and OSU, you'll find a fairly similar sort of list of tests that they are planning.

MR. SCHROCK: Dave, how detailed is the heat loss characterization planned to be? How much is lost in each component of the system and from the pipes, etcetera?

MR. BASSETTE: You can measure the total heat loss, and I think the question is how much can you attribute to the pressurizer versus the steam generator versus the vessel and so on.

MR. SCHROCK: The heat loss is a very complex business, and we tend to look at it overly simplistically, I'm afraid, and I reviewed a paper on heat losses, and I was intrigued by what you can get into if you really are going to characterize the heat loss well.

In these systems, the heat loss is probably more important than in the former evaluations.

So, how much thought has really been given to the adequacy of the heat loss characterization? That's really my question.

MR. BASSETTE: I think that's something we'll need to discuss a bit with JAERI.

MR. ORTIS: Remember that this is not a new facility. JAERI has a really detailed characterization of the heat loss.

MR. SCHROCK: Sure, but its characterization was for purposes of the past.

MR. ORTIS: The other thing I wanted to point out is that our new components are mostly cold. They are not hot.

MR. SCHROCK: What I hear you saying, Marcos, is that there isn't much need to do a better job than has been done previously.

MR. ORTIS: No, no.

MR. SCHROCK: My question is how much serious thought has been given to the question, and I guess what I'd like to find out, is it enough to ensure that it gets done correctly when it is done at JAERI?

MR. ORTIS: We're thinking about it seriously.

MR. BASSETTE: I read the heat loss report that JAERI wrote, and it just talks about the total heat loss.

MR. SCHROCK: Yes.

MR. BASSETTE: And that's about 150 kilowatts, and for 1 percent decay heat in ROSA, it's about, I think, 1 1/2 mega-watts or so. So, it's roughly like a percent of decay heat.

It's much more important where your heat loss is as much as your decay heat. You just can't use scale decay heat. You have to do something different.

MR. SCHROCK: I'm not exercising a judgement on how bad it is in ROSA. I'm just asking how much care has gone into evaluating -- how detailed an evaluation is going to be required in ROSA.

MR. BASSETTE: Yes.

MR. SCHROCK: So, for your item five, what I'm looking for is the planning that tells us that it's at the right level.

MR. BASSETTE: Yes.

MR. ZUBER: How fast is the interface received in the CMT?

MR. BASSETTE: How fast does it drain? Five hundred seconds or so.

MR. ZUBER: What is the velocity?

MR. BASSETTE: Twenty feet in 10 minutes.

MR. ZUBER: Okay.

MR. BASSETTE: It's two feet a minute.

MR. ORTIS: It's lower than that. It depends on the transient.

MR. BASSETTE: About two feet a minute, roughly.

MR. SHOTKIN: One of the CMTs will do it much quicker than that when the ADS is open. That's why it's not a very representative transient.

MR. DHIR: It's about 0.13 per second.

MR. CATTON: Is there a prototype test or one that's the same as what's being run in SPES?

MR. BASSETTE: We have a lot of counterpart tests with SPES.

MR. CATTON: You have a lot of them.

MR. BASSETTE: Yes.

MR. CATTON: Okay.

MR. BASSETTE: I think just about every one is probably a counterpart test of something in SPES.

MR. CATTON: That's fine. We'll hear about that later.

MR. BASSETTE: We had initially prepared this table about a year-and-a-half ago, and this is the same sort of phenomena that Mike Modro showed you. On the right is our expectation as to how well or qualitatively how well ROSA represents the phenomena that we have identified.

I don't know if I want to go through all the instrumentation, but we have instrumentation for the new equipment that we're installing in ROSA.

In the existing facility, there's only about 2,000 channels of instrumentation, and in the new equipment, we're adding about another 220 channels, and it's margins of pressure, DP, fuel temperatures and wall temperatures and flow, and I guess if we're going to have a future meeting on ROSA, we can go through in detail for each of these components and show you where these instruments are.

MR. DHIR: Are you going to have several of those or just one location?

MR. BASSETTE: There's several. There's one in the cold leg, pressure balance line, and there's one in the pressurizer service line, and there's one at the ADS.

Marcos, did we have a densitometer on ADS stage four or not?

MR. ORTIS: Yes, we do, on each one.

MR. BASSETTE: Okay.

MR. CATTON: Do you have enough DPs in the pressurizer to give a void fraction distribution?

MR. BASSETTE: We've got nine DPs.

MR. CATTON: In the CMT.

MR. BASSETTE: In the CMT, we have four plus an overall.

MR. CATTON: Isn't the CMT a little more important than the pressurizer?

MR. ORTIS: Yes, but the pressurizer had existing DPs. So, we didn't have to buy any new ones.

MR. CATTON: If Westinghouse is going to use some sort of a --

MR. BASSETTE: Well, DP is pretty important to the pressurizer, too, because -- DP is pretty important to the pressurizer, because it fills -- when you open the ADS, it fills with some two-phase mixture, and you get liquid going up there.

MR. CATTON: I understand, but in the CMT, if they're measuring level with some kind of a heat injunction -- it's going to have to be heated, even if it's an RTD, or else you're going to have a problem, but whatever it is, froth level is going to play a role.

So, the void fraction distribution and knowing what it is and where we're talking froth level, I think, is an important thing to get out of these tests. It may be a clean interface. I don't know.

MR. ORTIS: One of the limitations that Westinghouse imposes on the design is how fast the CMT drains, and the fastest rate would tend to be about a foot a minute.

MR. CATTON: But they activate the ADS based on what they're going to get out of these temperature measurements. The temperature measurements are going to depend on the two-phase distribution to the CMT.

I think it's an important aspect of what we're doing, is to find out what that is. Is four DPs enough? If it is --

MR. SHOTKIN: It's going to have to come from CMT tests. Here we're just using DP just as in SPES. We're not going to get the froth level.

MR. CATTON: But the CMT test run in SPES is really tall and skinny, and it could be that that could distort any void fraction distribution. Yours is flatter. We'll get maybe more into this when we have a whole day.

MR. SCHROCK: Do you have fittings on the vessel pressurizer and CMT in ROSA that wouldn't permit you to install a Stores Lens as you get into the experiment and may have questions about what really is going on in there?

MR. ORTIS: We have plenty of ports.

MR. SCHROCK: There are plenty of ports. That's what I'm asking. You think the Stores Lens is a ridiculous idea?

MR. ORTIS: No, no.

MR. SCHROCK: I'm asking Lou.

MR. SHOTKIN: We tried to use that. I don't know whether it worked or not. I think a viewing window itself might work.

MR. SCHROCK: Well, I can remember some things during the LOFT days where a Stores Lens was quite useful.

MR. CATTON: I remember from SEMISCALE where it was absolutely astounding.

MR. SCHROCK: Well, I just thought it might be a useful option if you get to the point where you can't understand the data well and you could look at it and see something.

MR. WULFF: Are the wall temperatures used? Are you using it for wall heat flux measurements, and if so, are they actual measurements or temperature difference?

MR. BASSETTE: Where we've put the most emphasis on wall temperatures has been on the CMT, and we have one string of thermocouples that measure temperature every foot of elevation and fluid.

We have a second string that's located at a second radial position that has four or five --

MR. ORTIS: It's less, for only half the CMT.

MR. BASSETTE: Near the top of the CMT, we have a second string, about four or five thermocouples in a second radial position, and then we have wall temperatures every two feet.

MR. ORTIS: Pairs.

MR. BASSETTE: Pairs. We have a wall temperature.

MR. WULFF: Are these very thick walls?

MR. ORTIS: An inch.

MR. BASSETTE: About an inch thick. And then we have one or two extra wall temperatures near the top of the CMT, in the dome region.

This is the test matrix as it currently stands. We've got one which is a no-break test.

We've got two tubes instrumented, an inner tube and an outer tube, and we've got -- for those two tubes, at three elevations, here, here, and here, we have a thermocouple and an overall external thermocouple, and so we have pairs. So, it's two, two, two, two, two, two there.

We've got a temperature measurement there.

MR. ZUBER: What about in the tank?

MR. BASSETTE: In the tank, we have tank temperatures. We've got one string.

MR. ORTIS: In addition to the string, we have a string of, I think, eight thermocouples in this side of the plant, and there are some thermocouples in the secondary of the tubes, near the tubes.

MR. BASSETTE: We've got a string, let's say, that's measuring the bulk tank temperature, and I think there's a thermocouple every two feet, and we have thermocouples located here, here in the fluid region, and here, here, and here within the tube bundle region, measuring fluid temperature.

MR. BOEHNERT: How tall is the tank?

MR. BASSETTE: Thirty feet.

MR. CATTON: How wide? Is that to scale?

MR. BASSETTE: It is about seven feet in diameter.

MR. ORTIS: What are you asking?

MR. CATTON: How wide the tank is.

MR. BASSETTE: It's about two meters, I think. Are you asking how wide is this?

MR. CATTON: From where the tubes come into the tank to the other side of the tank.

MR. BASSETTE: Okay. I think that's about seven feet or so. I think it's about two meters.

MR. CATTON: Thirty feet high, seven feet across.

MR. BASSETTE: Yes.

MR. CATTON: The recirculation ratio and everything in the tank is going to be very different because of the aspect ratio.

You should be sure you know all the temperatures because of that, because the temperature distribution in this pool will be very different than in the other pool.

MR. SCHROCK: You've got a lot of important temperatures in there, according to your table, and I think what's being suggested is it would be desireable to have a whole lot more in order to validate the RELAP5 modeling that you're doing on the secondary -- on the pool side heat transfer.

MR. BASSETTE: This tank is divided into two regions. The PRHR is on this side, and the sparger is on the other side.

We've got a thermocouple string right there, and that's about every two feet or so, and we've got additional thermocouples in the tube bundle region, both in the horizontal one and in the vertical one, and then we've got additional thermocouples on this side.

MR. SCHROCK: And the total number is greater than 11, as stated in this table?

MR. BASSETTE: Yes, I think so.

MR. CATTON: You're going to have some shake-down tests of this by itself, aren't you?

MR. BASSETTE: Yes. We're going to have some separate PRHR tests, and of course, we'll have the separate ADS tests.

MR. CATTON: You need to take a look and make sure that you have enough temperature measurements in the pool to do an energy balance.

MR. SHOTKIN: One thing that we've asked SHI to give us as a proposal is two upgrades to the instrumentation of the PRHR.

What Dave is showing you is the baseline cost estimate, and we're doing what we call a deluxe upgrade and a next-to-deluxe upgrade of instrumentation, and we want to get those cost estimates.

The problem is the exchange rate is going against us, and each yen that goes down is like several instruments. It's like 50K, 50-60K. So, the cost estimate is based on an exchange rate of 120 yen to the dollar, but it's now down to about 118.

At one time, it was up to 125, and we thought we could add some more instruments.

MR. DAVIS: Can't you buy them here and take them over?

MR. SHOTKIN: What?

MR. DAVIS: Can't you buy them here and take them over?

MR. SHOTKIN: Sure, but that's like 10 percent of the cost.

MR. CATTON: What happened to all the instruments from SCTF and CCTF? They just got left there, didn't they?

MR. SHOTKIN: Yes.

MR. ZUBER: Dave, how is it done in the Westinghouse CMT? How do they model that?

MR. BASSETTE: It's like a big tank which is kind of pinched in the middle. So, they have a -- it's like a big swimming pool that's about -- with a sparger on one side and the PRHR on the other side.

MR. CATTON: But the pools are connected.

MR. BASSETTE: The pools are connected. The connection is about 10 feet wide or so. This is a scaled connection opening.

MR. SEALE: When you say they're connected, you mean fully, to the top?

MR. BASSETTE: That's right, fully, from top to bottom.

MR. BOEHNERT: Is the layout prototypic of what's in the plant, locations of the stuff?

MR. BASSETTE: Everything is at the right elevation. We have a scale sparger, and the PRHR -- this is a scale horizontal one. We have a scale vertical one, full-size tubes.

MR. CATTON: The problem with this is going to be the stratification. In the other case, when the system is operational, you're really dumping hot water all in the top, and you have a huge volume to feed the cold water.

In this case, you don't have that. You're going to wind up with all the hot water just sitting on the top. So, the distribution is different.

You may have the volume of water right, but the distribution of the energy that winds up in the water is going to be very different because of the aspect ratio. So, you're going to have to be careful that you get enough data that you can bridge the gap via analysis.

MR. BASSETTE: The volume versus elevation is maintained.

MR. CATTON: You missed the point. The point is that the recirculation is very different. So, the part of the water that plays a role in the actual plant is different than the part of the water that would play a role here.

Just draw a picture with the circulation patterns on it and you'll see. You need to be more careful. You may need to put more instrumentation into this to account for the stratification.

MR. SHOTKIN: This is why we've asked for two estimates of more instrumentation.

MR. CATTON: Okay.

MR. SHOTKIN: We are at a cost limit on these facilities. So, we'll have to see what we give up in order to get the instruments.

MR. CATTON: Well, maybe you'll get to the point where you have to push for more money. If the data is going to be compromised because you don't put a few instruments in there, I think that's a different kind of calculation you have to do.

MR. BASSETTE: This distance from here to the wall, let's say, is a factor of six reduced in ROSA compared to AP600.

MR. CATTON: I think you still don't understand what the problem is. The problem is the aspect ratio.

MR. BASSETTE: Well, that's what I just said.

MR. CATTON: The recirculation takes place over a big broad area, and a lot of the energy that's dumped into the pool is on the top, spread over this whole big area.

MR. BASSETTE: The factor of six is that distortion. In ROSA, let's say if this is -- from the PRHR to the wall, let's say, if it's three feet in ROSA, it's 18 feet in AP600.

MR. SEALE: Is the scaling on the total diameter of the tank or on the part of the tank that's sticking out of the wall?

MR. BASSETTE: The scaling is -- it's full-height and preserving volume, which means that the radius gets smaller.

MR. SEALE: I understand that, but the volume you're expanding to and spreading over in the case of the ROSA pool is the whole volume. In this case, it will be one-sixth of the volume. It will be the proportionate volume but truncated by that wall you've got in there. So, the scale factor is maybe 10 instead of 6.

MR. ZUBER: And you put a partition for what reason, exactly?

MR. BASSETTE: Well, we tried to represent the AP600. In the AP600, the sparger is there, and the PRHR is there, you know, and it's the same connected pool of water, but --

MR. ZUBER: The liquid will spread in the process. What you're really doing -- you are really actually limiting it.

MR. BASSETTE: This opening represents the -- it is a scaled connection between these two points of the pool and the plant, and this connects from top to bottom.

So, if you put heat, let's say, into this side, the water is going to flow up, and it's going to want to flow in there and get replaced by colder water coming down to the bottom.

MR. CATTON: In the process, too, it has to go back around to get out.

MR. SHOTKIN: At one end is the PRHR, at the other end is the ADS sparger, and in the middle is this connection between the two.

What Ivan is talking about, the spreading over the top, you expect to occur certainly in one end of the horseshoe, but then when it gets to that constriction over there, it might be less, and that's scaled over here.

We have that small 120-millimeter part in the neck of the horseshoe.

MR. CATTON: But Lou, if that opening between the two sides is 10 feet wide, then you're going to have mixing in the stratified layers that will flow into the other side, as well --

MR. SHOTKIN: Yes.

MR. CATTON: -- unless it's heated up because of the sparger.

MR. SHOTKIN: Right.

MR. CATTON: And you've put the connection down in the corner there. I guess it's across, but it's near the wall.

I'm not sure what the flow patterns on the surface as a result of the plume are going to be, but it's going to be more up where the tubes are vertical than it is back at this end.

So, some of the geometries are different, but I don't think that's as important as the constriction due to the high aspect ratio.

MR. SHOTKIN: Okay.

MR. WARD: Is the water in the pool cool?

MR. BASSETTE: Yes. It starts off at 75 degrees Fahrenheit or under.

MR. WARD: Okay. Is there any heat removal during the test?

MR. BASSETTE: No, not during the test.

MR. WARD: It heats up.

MR. BASSETTE: Yes.

MR. DHIR: Most of the heat is removed by drying anyway.

MR. CATTON: That's a slow process.

MR. DHIR: After a while, it will be saturated at the bottom.

MR. WARD: I don't think that instrumenting the pool is going to tell them an awful lot that will help in developing the model. It's a very different experimental model.

MR. CATTON: You're absolutely right, but if they develop a model that's appropriate and if they treat this one properly, they can couple the two, and we can make sure they get enough data to do that.

MR. BASSETTE: This is the total tank. It's about 30 feet tall. The water level is at 28 feet, and the PRHR sits here. This is about -- the vertical section is about 18 feet. This horizontal one is about seven feet.

MR. CATTON: How much of the pool is below that bottom horizontal rim?

MR. BASSETTE: Three feet.

MR. SCHROCK: Could we look at the other picture for a second, Dave? That 12-centimeter interconnection is above the horizontal tube level. Would it not be better to put it up at the other end, so that they are not getting the crossover right in the plume?

MR. BASSETTE: Put it up here?

MR. SCHROCK: Uh-huh. Well, if you're going to develop a simpler model instead of the RELAP5 thing that you've been trying so far, it would work better. If you have that communication mixed up with the details of the plume, it's going to complicate that.

MR. CATTON: We're rapidly approaching the witching hour. Can I get you to move on to the SBWR? And if you could, keep it to 10 minutes.

MR. BASSETTE: I can't say anything on this, because we're in the middle of the contract. How's that?

I'm just going to kind of pull from the RFP. Of course, the general objective is to get confirmatory test data, looking at the emphasis on weight, de-pressurization into the GDCS, draining it into operation of the PCCS.

So, the RFP calls for inclusion of all the major components, the reactor vessel with a heated core, containment that includes the dry well, upper dry well, lower dry well, the connection to the suppression pool -- I think GE is calling the vapor space above the pool now a suppression chamber -- the vent valves, the vacuum breaker valves between the dry well and the suppression chamber, and of course, the Weir with the horizontal vents between the dry well and the pool, and also the GDCS system and the PCCS system with its passive venting.

This is just a list of issues: GDCS performance or draining. We're going to look at different failures and different line breaks; assess the PCCS performance, particularly the passive venting; the effect of non-condensables on the heat exchange; systems and directions.

That shows the test matrix should cover a broad range of conditions and single failures.

The proposal has five tasks. First is a PIRT-type process identifying important phenomena, to develop a scaling rationale based on that where your scaling includes addressing important phenomena, a test matrix, and facility design.

These are the kind of things that we have to do in preparing the proposal or at least get started on.

Task two is to complete a detailed design, prepare a design report, and then start to procure the equipment, construct it, and then test the test program.

There's the status. We had the RFP published in Commerce Business Daily in November, closing date was January. We've had our Source Evaluation Panel review.

The contract award is schedule for May or June, design completion by the end of the year, construction by the middle of next year, and then a testing phase, and this is just showing where we're trying to get information.

The FSER is due for October of '94, and again, I think the actual date has probably slipped six months. So, we have until about April of '95.

That's about it. We can tell you a lot more in June, when the contract is done.

MR. CATTON: That sounds fair to me.

I'd like to thank everybody for participating, appreciate your being here.

I'd like the consultants to write me a nice report.

First, I'd like to know what issues you think are important for our review of Westinghouse, and what did you see during this day-and-a-half that deserves more of our attention?

With respect to RELAP5, our review of Volume 4 -- and here, it doesn't have to be done right away, but also as a part of RELAP5, any comments you have on the improvements that were suggested by Berta, general comments on what you heard.

I'd like the bad with the good, and if you could offer constructive criticism, I would appreciate it, particularly constructive, because we're really trying to be helpful, even though you may not think so.

MR. SHERON: What I would ask, also, if it's possible, would be that, if you do have comments or criticisms or constructive criticism, if you can put some kind of relative importance on it in your mind.

MR. CATTON: We may need to interact on that, because sometimes we base importance based on what we have heard from you or from your people when they make a presentation, and the emphasis that they put on it sometimes leads us to something, and it may not be right.

MR. SHERON: One way to just say it is that, if the consultants -- I mean if they have 10 concerns, it would be helpful to know what they think we ought to be working on first, as opposed to last.

MR. CATTON: That's fair enough, and what I would like, maybe, is if you and Paul could talk, because he made a lot of comments this morning, and I don't remember what they all were.

MR. DAVIS: I told Brian I'd have the committee draw up a list of action items from this meeting, and we'll go back and forth and make sure they're right.

MR. CATTON: Okay.

Anybody care to make any closing remarks? If not, I'm going to adjourn the meeting.

[Whereupon, at 11:55 a.m., the meeting was adjourned.]

REPORTER'S CERTIFICATE

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

NAME OF PROCEEDING: ACRS Thermal Hydraulic Phenomena

DOCKET NUMBER:

PLACE OF PROCEEDING: Idaho Falls, Idaho

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.

Shari Bowman
Official Reporter
Ann Riley & Associates, Ltd.

Idaho
National
Engineering
Laboratory

IMPROVEMENTS TO RELAP5/MOD3 FOR ALWRS FROM DESIGN REVIEW AND INITIAL PLANNING (SECOND TIER)

Presented by
V. T. Berta (Victor)
Thermal Systems Code Development and Analysis Unit
EG&G Idaho, Inc

ACRS Thermal Hydraulic Phenomena Subcommittee Meeting
March 4-5, 1993
Idaho Falls, Idaho

Second Tier Improvement Areas to RELAP5/MOD3

- Downcomer Nodalization
- ADS and Sparger Condensation
- Steam Separator
- Spherical Accumulator
- Computational Improvement for Long Transients

c005-rbn-0293-002

Downcomer Nodalization

- Improvement:

  Calculation of downcomer condensation in the AP600 in which cool liquid flows into a downcomer filled with hot steam.

- Observation:

  Unrealistic phenomena calculated in the AP600 downcomer; attributed to incorrect condensation.

- Status:

  Subsequent to identification of improvement, user nodalization studies led to a nodalization scheme that eliminated the calculation of unrealistic phenomena. Improvement in this area is not planned currently because of higher priority tasks.

ADS and Sparger Condensation

- Improvement:

  Condensation modeling of steam flow through the AP600 ADS valves and SBWR safety/relief valves and release through the spargers into the IRWST and suppression pool, respectively.

- Observation:

  Plausible condensation phenomena is being calculated in the IRWST. However, the behavior is known to be influenced by node size and the optimum noding is not yet established.

- Status:

  A literature search is underway (with some success) to locate applicable models and correlations. The selection process will be based on the ranges of experimental data used in model/correlation development and comparison with data.

ADS and Sparger Condensation (cont'd)

- Status (contd):

  Candidate models and correlations will be put into a test version of RELAP5/MOD3 for purposes of comparing calculations with data. These comparisons will be the basis for assessing code performance for steam condensation in a liquid pool. Final selection will be limited to no more than two models/correlations.

Steam Separator

- Improvement:

  A more mechanistic steam separator model to replace the idealized model currently in the code.

- Observation:

  The current model (for PWR SG separators) is not mechanistic and does not represent SBWR separator performance.

- Status:

  The mechanistic model of the GE centrifugal separator, which was developed for the TRAC-BWR code, has been recommended and approved for placement in RELAP5/MOD3. Also, the simple steam dryer model, developed for TRAC-BWR, will be placed in RELAP5/MOD3.

  The current separator model is considered adequate for PWRs except for steam line break conditions. For these conditions, the PWR separator model developed at MIT is recommended to be added as an option to the current separator model.

  These improvements are scheduled for FY-93 funding.

c005-rbn-0293-006

Spherical Accumulator

- Improvement:

  Extend code capability to include the unique modeling requirements for spherical accumulator tanks.

- Observation:

  The momentum equation and the heat and mass transfer correlations must be modified to use the volume, flow area, and surface area of a spherical tank geometry (which are dependent on a variable tank cross-sectional area).

- Status:

  This improvement has been added to the code. Included are:

  a. An input option to define cylindrical or spherical geometry.
  b. A function to calculate volume and flow area for a spherical tank.
  c. A generalization of the acceleration terms in the fluid momentum equation to handle a tank of variable cross-section.
  d. Heat and mass transfer correlations for a spherical tank.

c005-rbn-0293-007

Computational Improvements for Long Transients

- Improvement:

  Reduce the run time of the code sufficiently to allow calculation of long transients of up to 3-day duration.

- Observation:

  Run time reduction of at least a factor of ten is desired to make 3-day transient calculations feasible.

- Status:

  Interest in code run time reduction has been expressed by the NRC, Bettis Atomic Power Laboratory, and Westinghouse Savannah River Company (WSRC). A proposal has been prepared to reduce the code run time by an estimated factor of ten.

  The proposal is based on improvements in the areas of:

  a. Time step advancement
  b. Solution efficiency
  c. Parallel processing

Computational Improvements for Long Transients (cont'd)

- Status (contd):

  Sponsor objectives:

  NRC Capability of long (3 days) calculation of ALWR transients.

  Bettis Capability of using current and future generation computer structure (parallel processing) in conjunction with a faster running code with 3D graphics display in an input preprocessor and in an improved NPA.

  WSRC Capability of RELAP5/MOD3 to drive reactor simulators in real time for operator training.

Computational Improvements for Long Transients (cont'd)

- Status (contd):

Specific improvements are proposed as follows:

Time step advancement Objective: run at increased time steps.	1.	Increased implicitness to improve robustness of the code.
	2.	Time step control function: a. time step size b. automate degree of implicitness
Solution efficiency	1.	Domain decomposition
	2.	Addition of new direct solvers (user options)
	3.	Addition of iterative solver (user option)
Parallel processing	1.	Addition of parallel processing capability for any number of processors.

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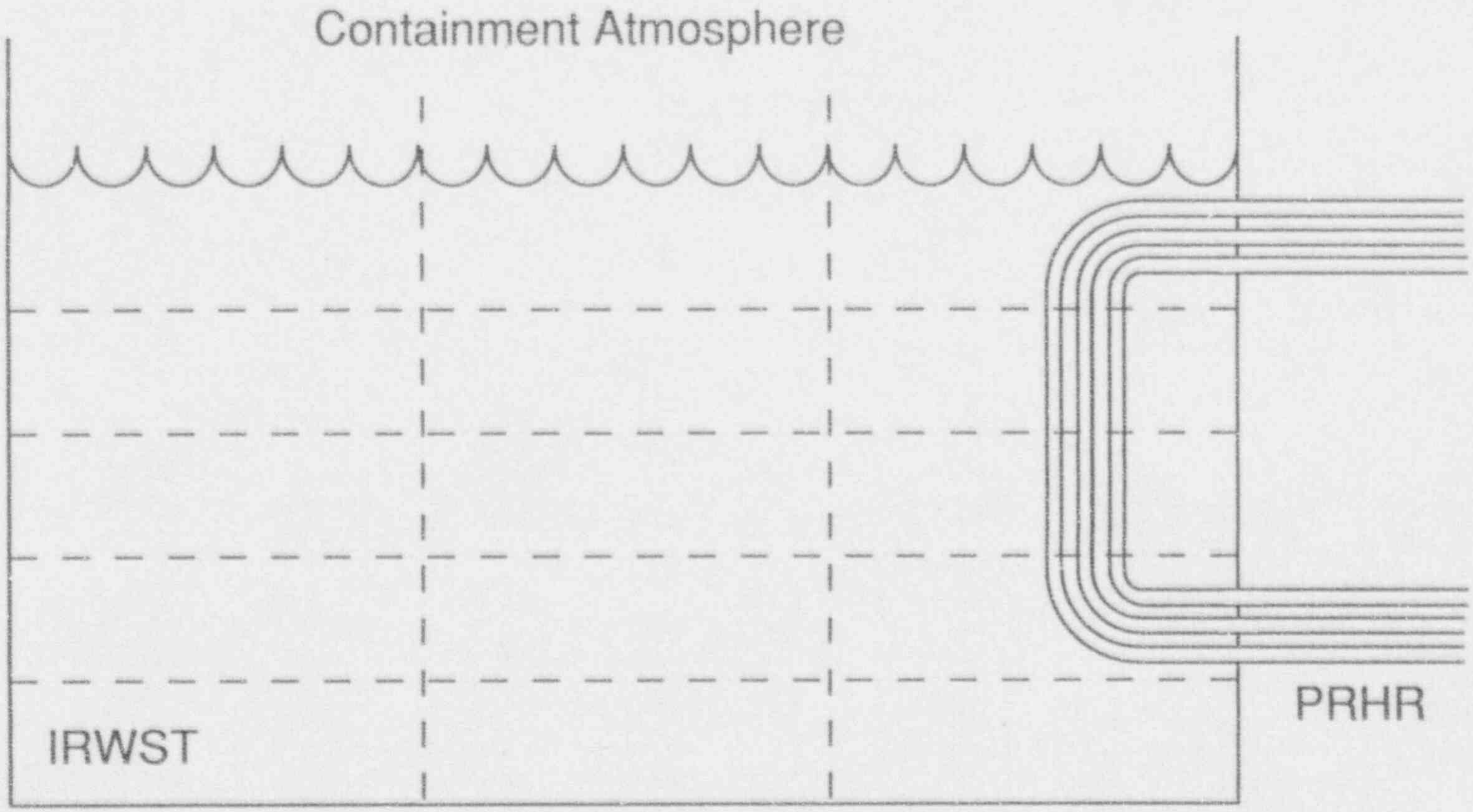
Modeling the PRHR/IRWST

Presented by
Gary W. Johnsen

ACRS T/H Phenomena
Subcommittee Meeting

Idaho Falls, ID
March 4, 1993

PRHR Heat Exchanger in the IWRST Presents New Challenges



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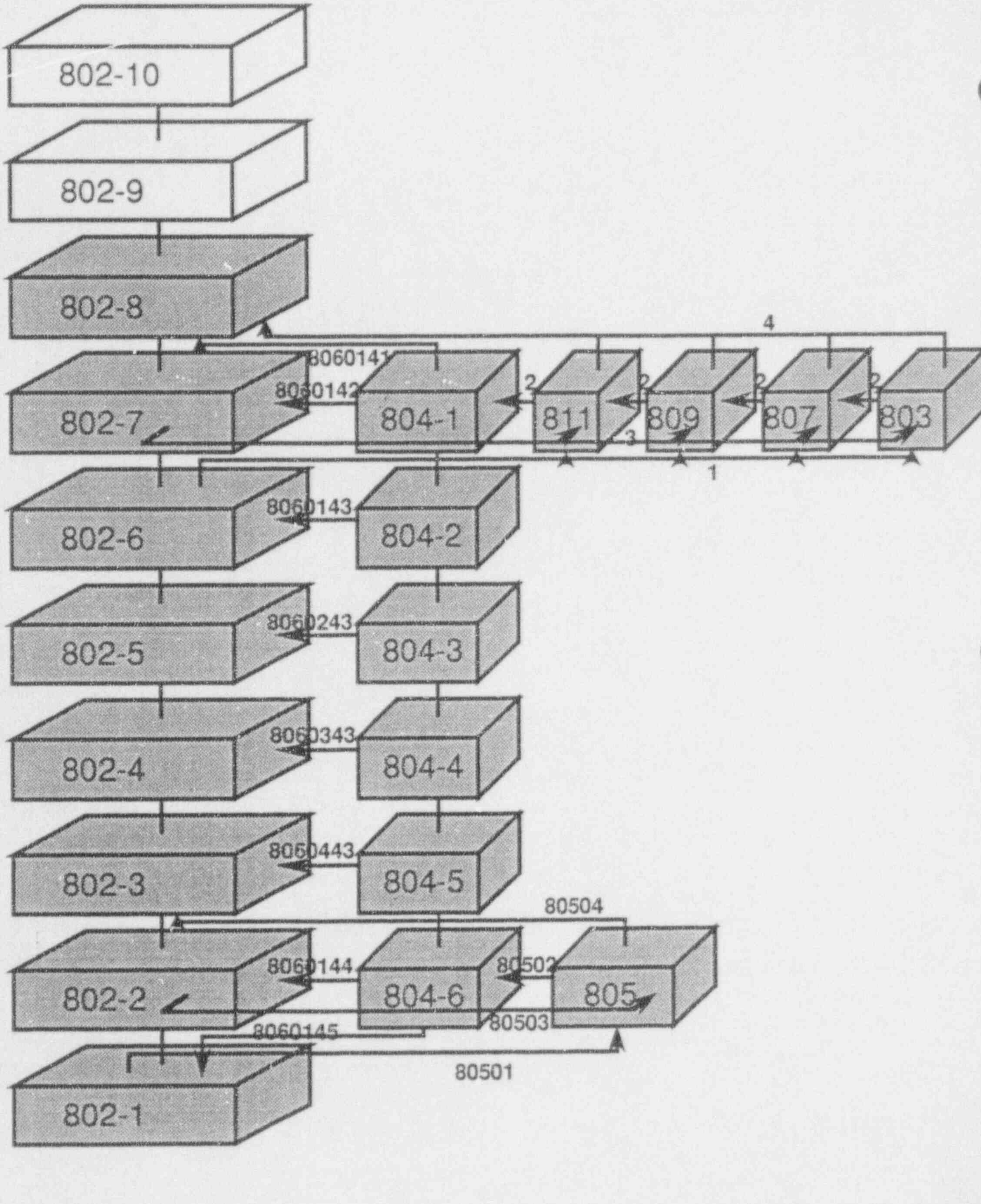

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Modeling Issues Identified Thus Far

- Recirculation of IRWST coolant in vicinity of PRHR tube bank
- Partial uncovery of PRHR tubes
- Nodalization of IRWST
- Faulty donoring of air into IRWST (RELAP5 problem)

c003-rbn-0293-003

Results To-Date

- "Lumped IRWST model (i.e., axial noding only) runs successfully
- Air ingress into IRWST pool "cold side" causes code failures
- Further diagnostic work in-progress

c003-rbn-0293-004

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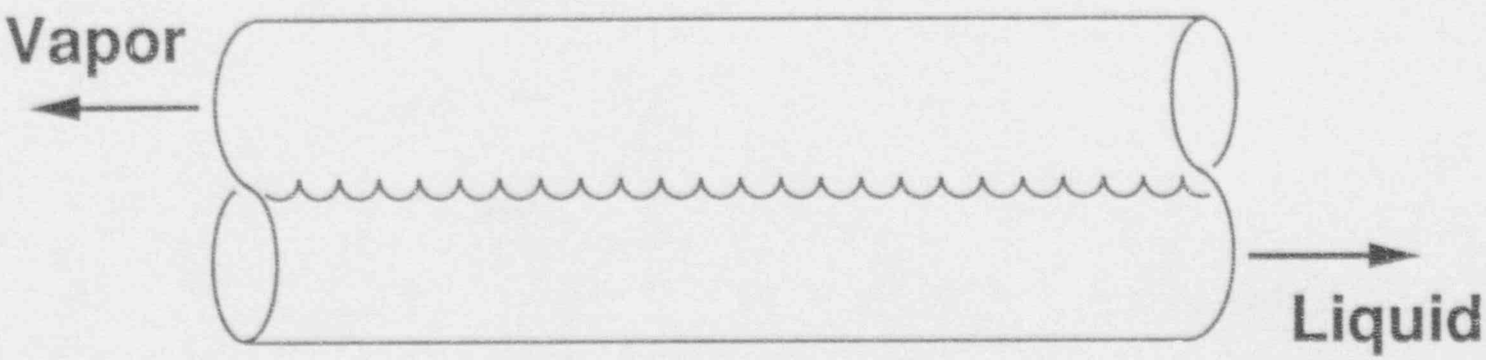
Modeling Horizontal Countercurrent Flow With RELAP5

Presented by
Gary W. Johnsen

ACRS T/H Phenomena
Subcommittee Meeting

Idaho Falls, ID
March 4, 1993

The six equation hydrodynamic model inherently permits horizontal countercurrent flow (HCCF)

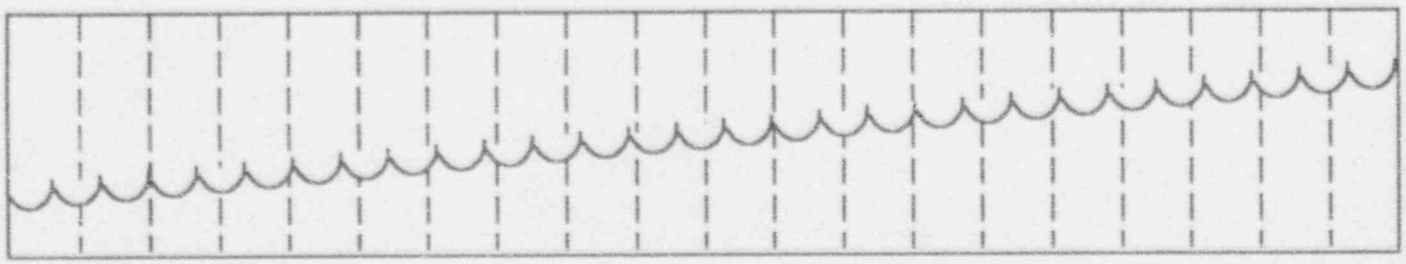


If the appropriate conditions prevail

Conditions Appropriate to HCCF:

- Stratified Flow Regime (Taitel-Dukler Criterion)
- Liquid level gradient in axial direction (gravity term in momentum equation)

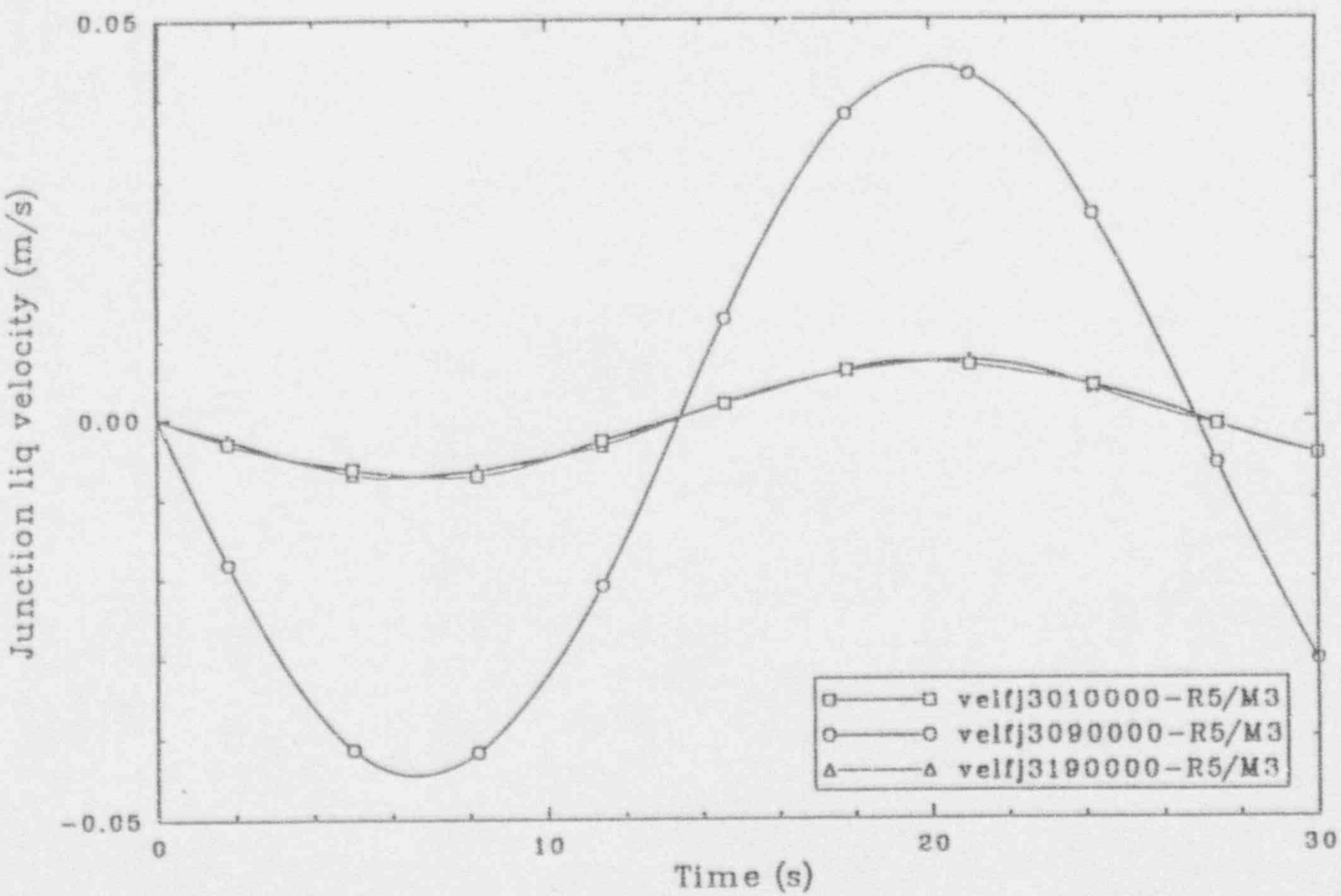
Horizontally Stratified Countercurrent Flow Test Problem



20 Volumes

c004-rbn-0293-005

Calculated Liquid Velocities at Ends and Middle of Pipe



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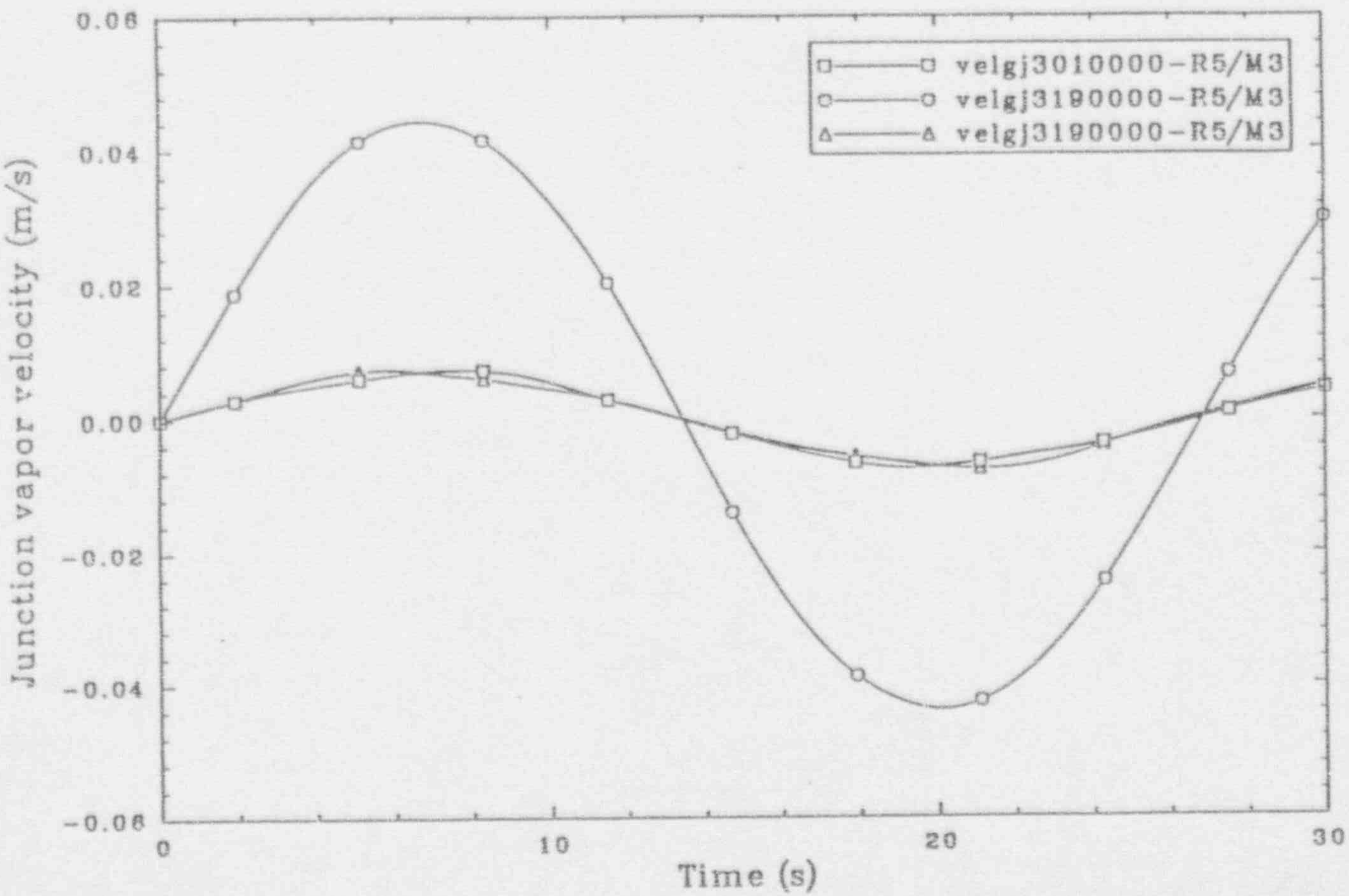
Calculated Vapor Velocities at Ends and Middle of Pipe



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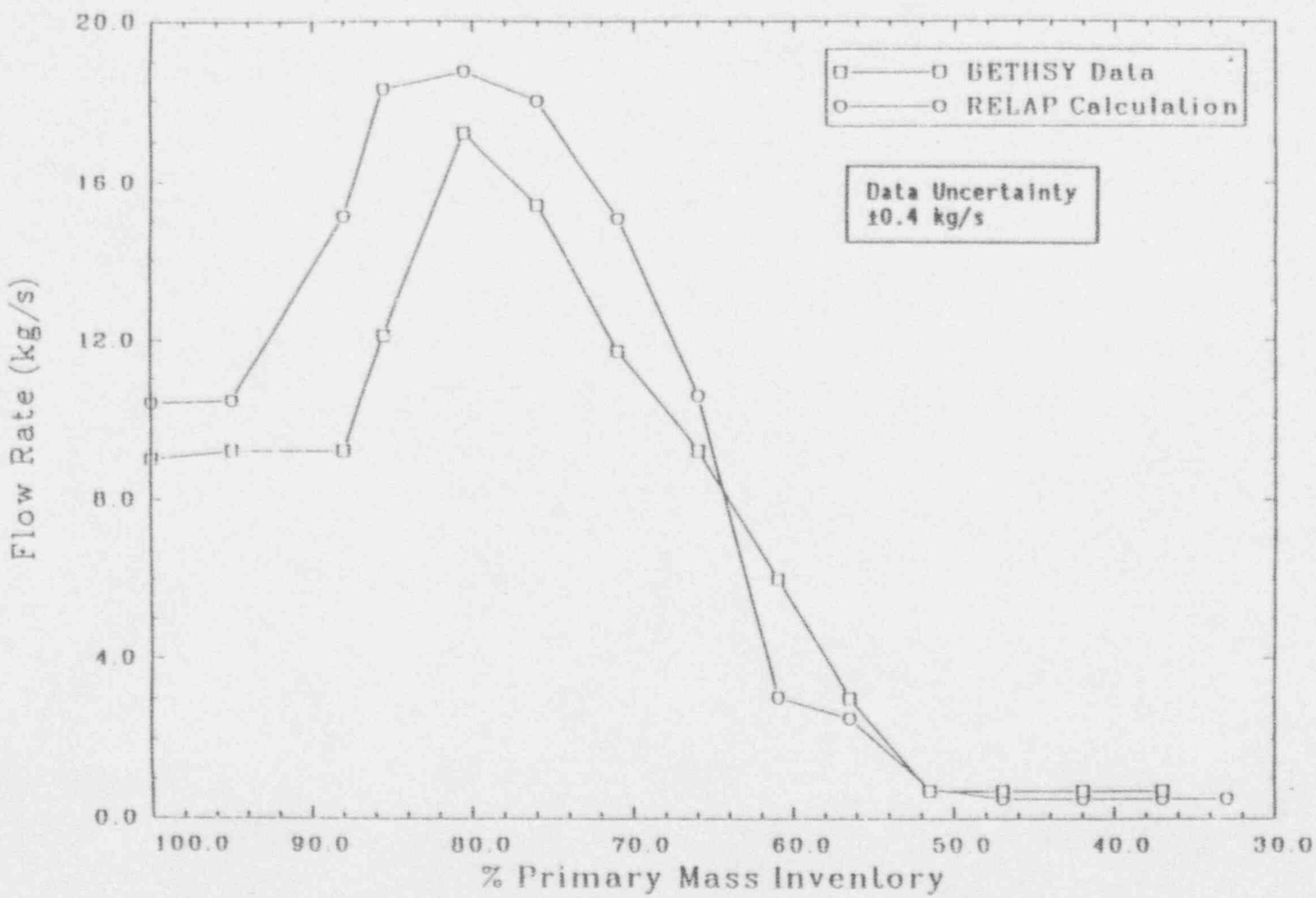
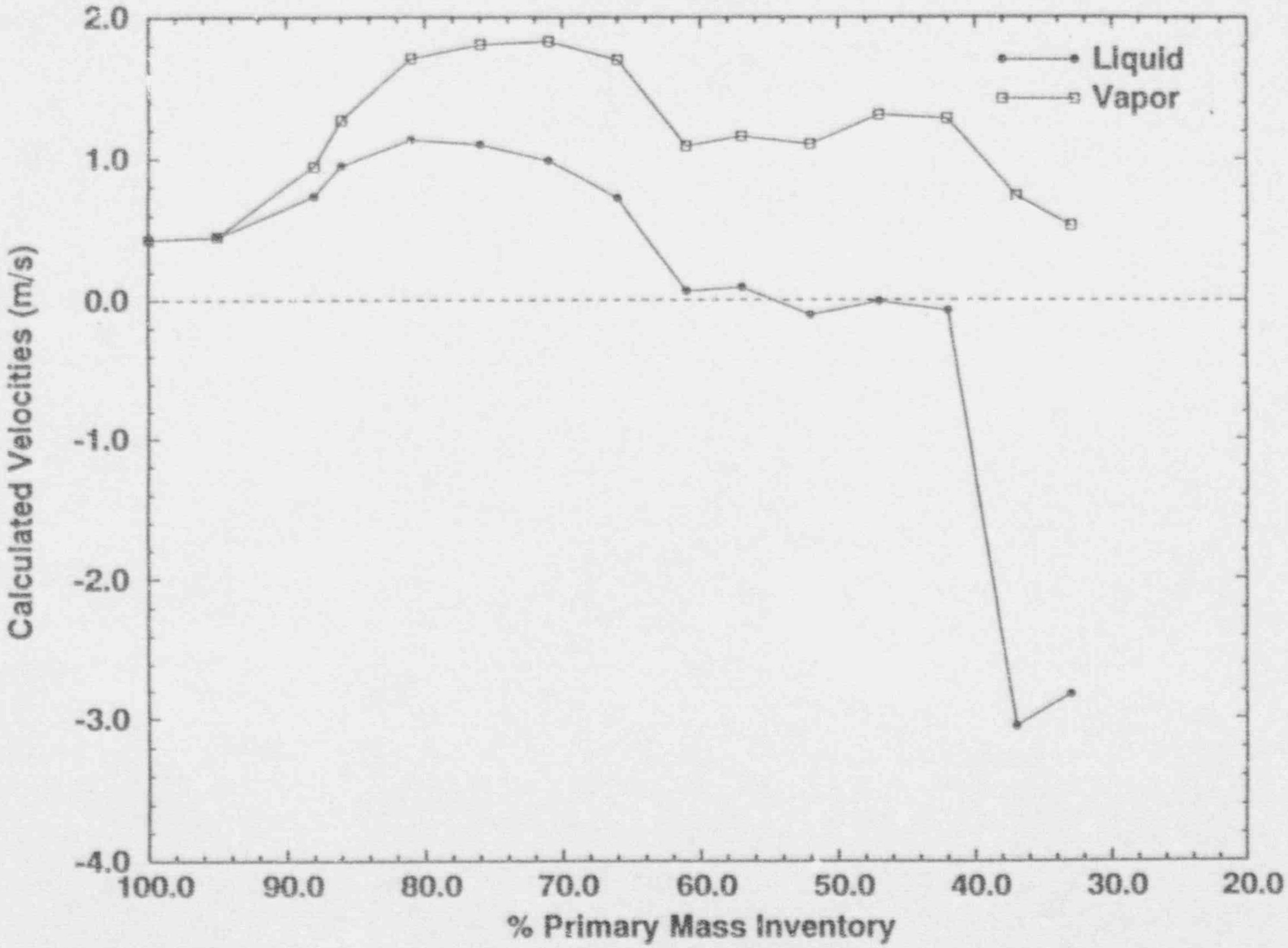
Measured and Calculated Downcomer Coolant Flow Rates as a Function of Coolant Inventory - BETHSY Test 4.1a-TC



Calculated Liquid and Vapor Velocities in the BETHSY Hot Leg as a Function of Coolant Inventory - BETHSY Test 4.1a-TC



TESTING & MODELING

OF

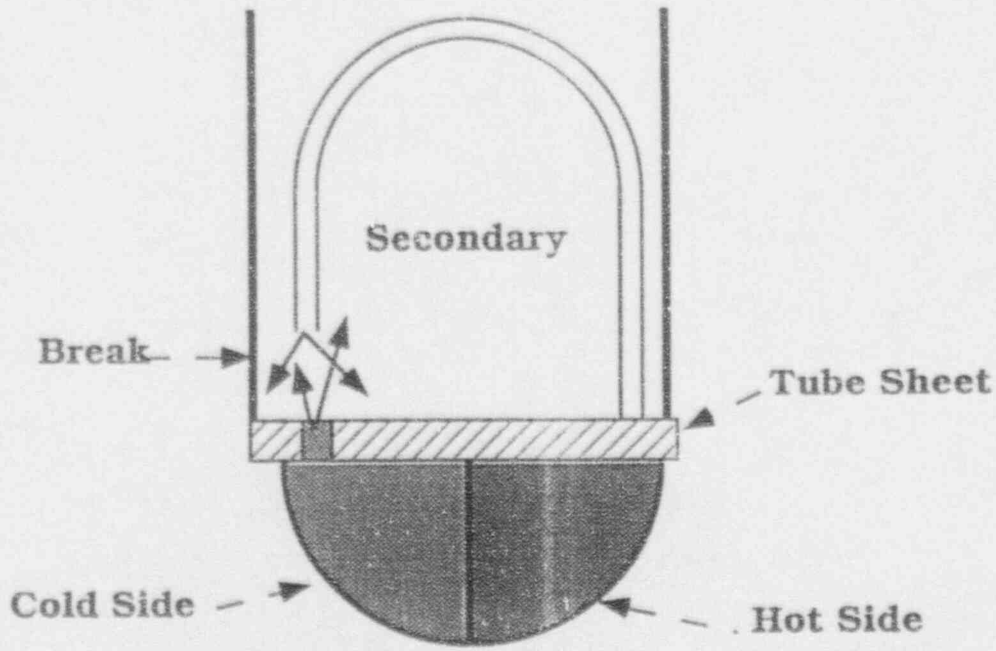
STEAM GENERATOR

TUBE RUPTURE

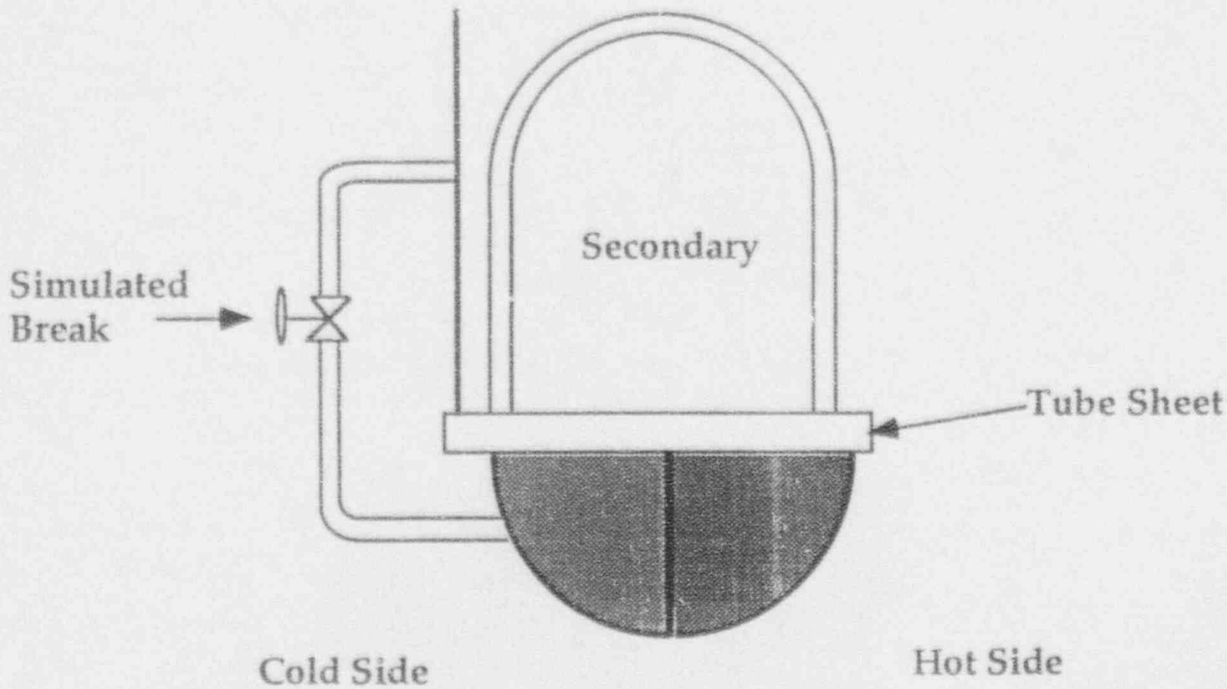
Presented to the Advisory Committee on Reactor Safeguards
Thermal-Hydraulic Subcommittee Meeting

INEL
Idaho National Engineering Laboratory

Presentation by:
S. M. Modro
March 5-6, 1993
Idaho Falls, Idaho



Schematic Description of A Steam Generator Tube Rupture



SCHEMATIC DESCRIPTION OF EXPERIMENTAL SIMULATION OF THE STEAM GENERATOR TUBE RUPTURE

PHENOMENA NOT CAPTURED IN THE EXPERIMENT

- **MASS FLOW OUT THE BREAK**
  (Experiment is conservative)

- **INTERACTION BETWEEN THE BREAK FLOWS**
  (Experiment has only one jet)

- **LOCAL 3-DIMENSIONAL EFFECTS**
  (Break location and configuration are distorted)

IMPACT OF DISTORTIONS

- **ON CODE VALIDATION & ANALYSIS:**
  NONE.
  This code is set up to simulate actual situation being examined: either the experimental configuration or that of the real system.

- **ON OVERALL SYSTEM SAFETY: NONE.**
  The experimental configuration is likely to yield a greater flow than the real one.

- **ON OPERABILITY OF THE EXPERIMENT: IT MAKES IT POSSIBLE.**
  Even if one were able to recreate the actual breaking of a single tube inside a bundle in the experimental situation; it would be very difficult to instrument (with proven and existing instruments) both sides of the break and the affected secondary, to measure the break flows and 3-Dimensional effects present.
  solutions, design concepts, analyses and testing capabilities.

COMPONENT MODELING ISSUES

Presented to the Advisory Committee on Reactor Safeguards
Thermal-Hydraulic Phenomena Subcommittee Meeting

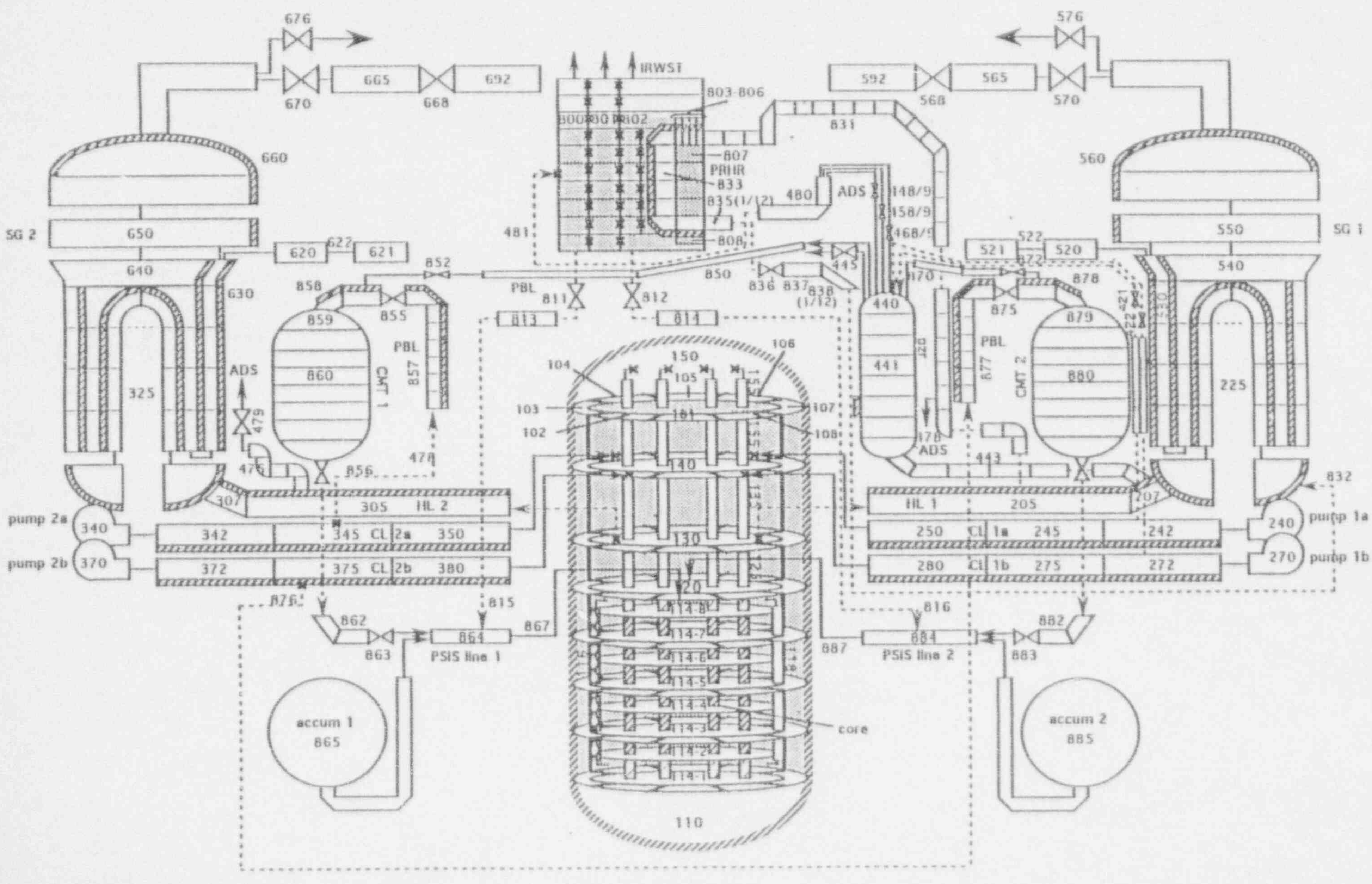
INEL
Idaho National Engineering Laboratory

Presentation by:
S. M. Modro
March 4-5, 1993
Idaho Falls, Idaho

DISCUSSED COMPONENTS

- CMT
- PRHR
- IRWST
- SURGE LINE
- ADS
- STEAM GENERATOR COLD SIDE PLENUM
- PRESSURIZER
- DOWNCOMER

RELAP5 NODALIZATION SCHEME FOR AP600

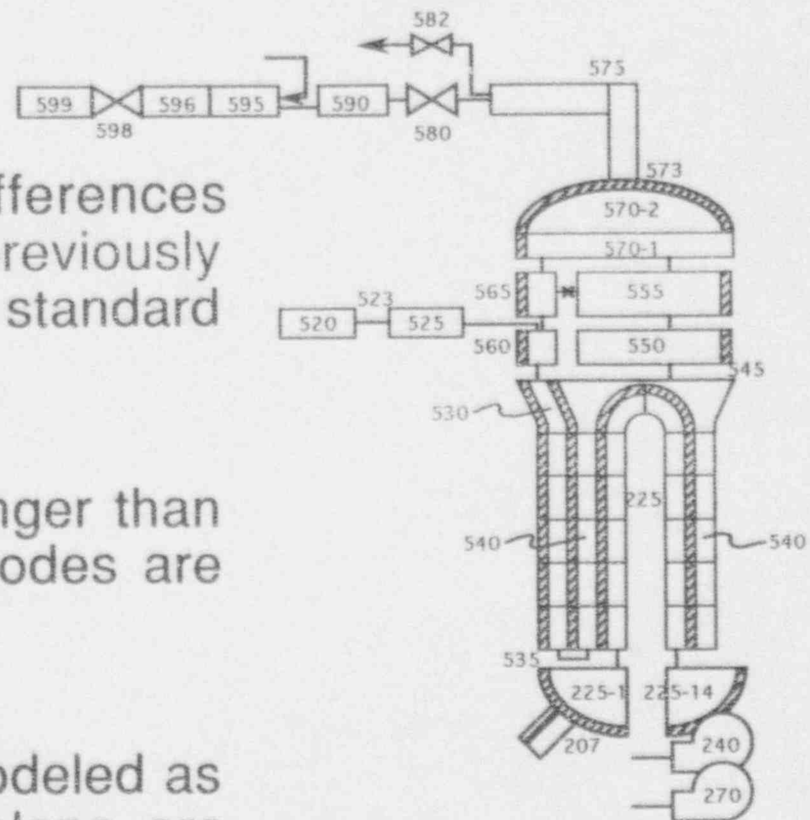


NODALIZATION OF THE AP600 AUTOMATIC DEPRESSURIZATION SYSTEM (ADS)

- Currently, there is insufficient data to construct a representative model.

- The approach to nodalization will be to limit L/D to 8 in order to accommodate line losses and form losses in calculating back-pressure, choking, and delta-P's.

NODALIZATION OF THE AP600 DELTA-75 STEAM GENERATOR

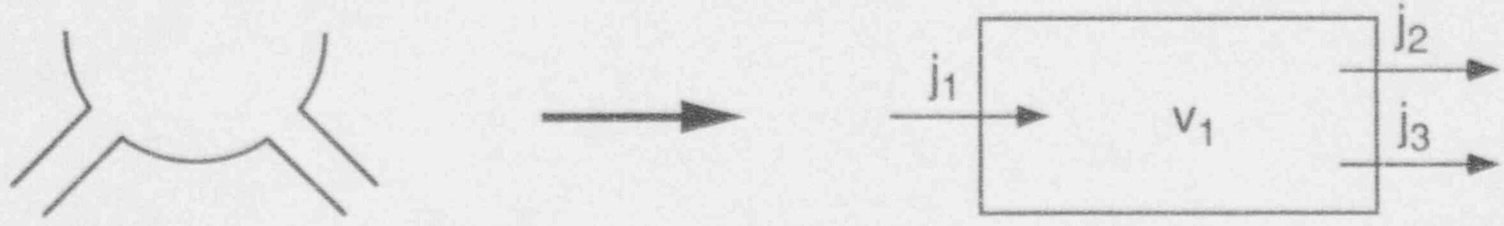


- There are no significant design differences between this U-tube SG and those previously modeled which call for deviation from standard SG modeling practices.

- Since the tubes are about 12 foot longer than those in a Model F SG, four more nodes are used to model them.

- The inlet and oulet plena are each modeled as a single pipe volume because the plena are virtually the same as in previously modeled SGs. No new phenomena are anticipated in the outlet plenum (due to the two pump connnections) that would require deviation from standard modeling practices.

The RELAP5 Branch Component is used to model the steam generator outlet plenum:



The volume velocity used in the momentum flux term $(1/2\ \alpha\rho \frac{\delta v^2}{\delta x})$ in the momentum equation is given by:

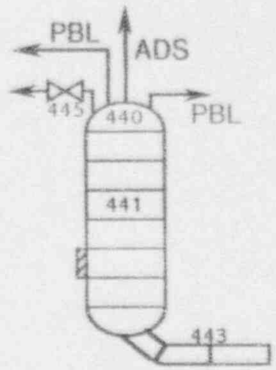
$$V_{v_1} = 1/2\overline{V}_{v_1,in} + 1/2\overline{V}_{v_1,out}$$

where $\overline{V}_{v_1,\,in} = V_{j_1}$

$$\overline{V}_{v_1,\,out} = \frac{(\alpha\rho vA)_{j_2} + (\alpha\rho vA)_{j_3}}{(\bar{\alpha}\bar{\rho}A)_{v_1,\,out}}$$

NODALIZATION OF THE AP600 PRESSURIZER

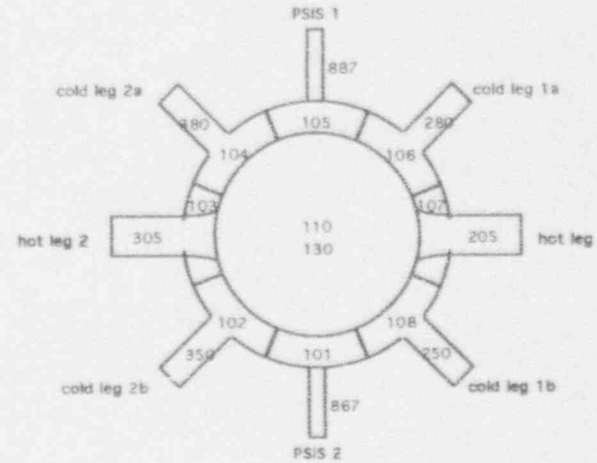
- The pressurizer nodalization conforms to standard nodalization schemes (i.e., Surry), which are predicated upon tracking pressurizer pressure and level.

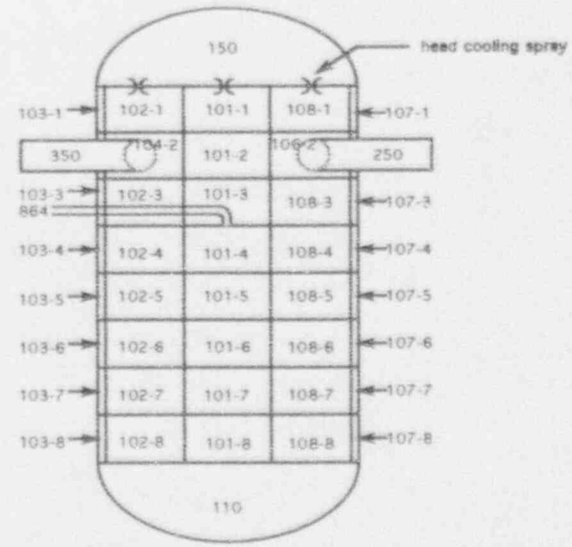


- Nodalization sensitivity studies are needed to quantify mixture level tracking.

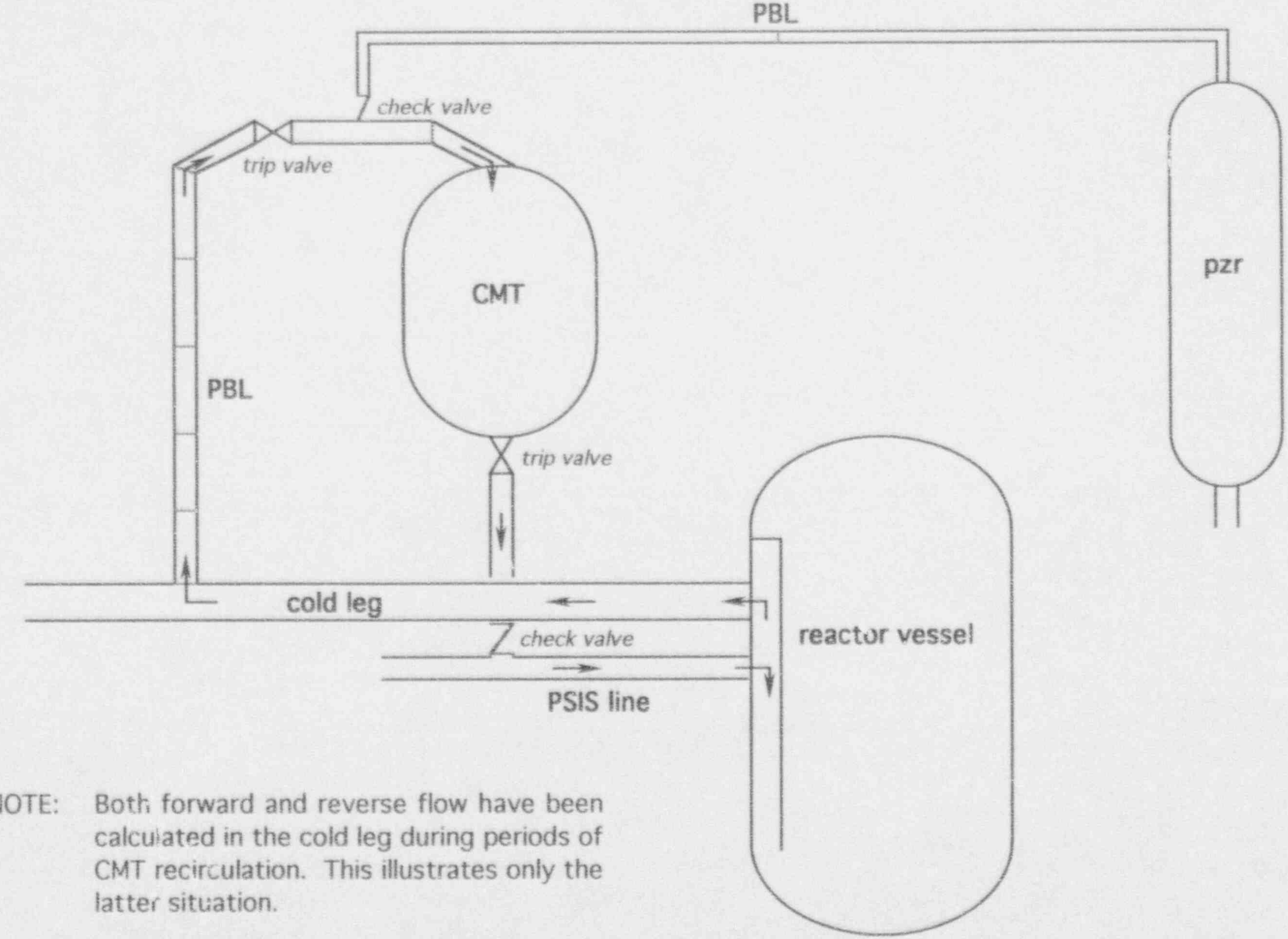
NODALIZATION OF THE AP600 DOWNCOMER

- The downcomer nodalization is such that the code can predict the following):
  - CMT recirculation from the downcomer (see related diagram)
  - temperature profile around the downcomer during ECC injection (colder below the DVI nozzles)
  - boron transport in the downcomer





CMT RECIRCULATION (FROM REACTOR VESSEL)



NOTE: Both forward and reverse flow have been calculated in the cold leg during periods of CMT recirculation. This illustrates only the latter situation.

EXPERIMENTAL PROGRAMS ROSA-V AND SBWR LOOP

DAVID E. BESSETTE

ACRS THERMAL HYDRAULIC SUBCOMMITTEE MEETING

IDAHO FALLS, IDAHO

MARCH 4-5, 1993

MILESTONES IN ROSA/AP600 PROGRAM

COMMISSION AUTHORIZES ROSA/AP600 PROGRAM
AUGUST 11, 1992

SHI SIGNED NONDISCLOSURE AGREEMENT AUGUST 26, 1992

SOLICITATION ISSUED TO SHI SEPTEMBER 1, 1992

NRC/JAERI/SHI MEETING AT JAERI SEPTEMBER 4-10, 1992

MODIFICATION TO SOLICITATION ISSUED TO SHI ON
SEPTEMBER 24, 1992

NRC JAERI ROSA/AP600 BILATERAL AGREEMENT SIGNED
OCTOBER 5, 1992

SHI PROPOSAL RECEIVED NOVEMBER 4, 1992

NRC/SHI LETTER CONTRACT SIGNED NOVEMBER 27, 1992

PUBLISHED "INVESTIGATION OF THE APPLICABILITY AND LIMITATIONS OF THE ROSA LARGE SCALE TEST FACILITY FOR AP600 SAFETY ASSESSMENT," NUREG/CR-5853, DECEMBER 1992

NRC/JAERI/SHI MEETING AT NRC FEBRUARY 10-17, 1993

NRC/JAERI/SHI MEETING MARCH 15-17, 1993 AT SHI

MILESTONES IN ROSA/AP600 PROGRAM (CONT'D)

FINAL CONTRACT TO BE SIGNED BY MARCH 31, 1993

RESIDENT ENGINEER DUE TO ARRIVE AT JAERI APRIL 1993

MODIFICATIONS TO LSTF SCHEDULED TO BE COMPLETED DECEMBER 1993

THREE AP600 TESTS SCHEDULED FOR JANUARY-MARCH 1994; ADDITIONAL SEVEN TESTS TO FOLLOW

FSER TO COMMISSION/ACRS NOVEMBER 1994

配布先			

発行日	承認	審査	担当

SCHEDULE

'93

名称		Month	2	3	4	5	6	7	8	9	10	11	12
Contract													
Design							○						
Fabrication		○							○				
Instrumentation			○							○			
Structute / Foundation							○		○				
Installation								○					○
Facility Inspction Acceptance Test												○	○

備考

見積番号		納入先		品名		納入条件		分類		1/1
製作番号						納期	年 月 日			

住友重機械工業株式会社

3 [illegible] during January–March, 1993

SCALING BASIS OF ROSA/AP600 MODIFICATIONS

1:30 VOLUME SCALE

FULL HEIGHT, PRESERVE ELEVATIONS

PRESERVE PIPING PRESSURE DROPS

PRESERVE COMPONENT VOLUMES

LIST OF EQUIPMENT

CORE MAKEUP TANKS (2)
PRESSURIZER PRESSURE BALANCE LINES (2)
COLD LEG PRESSURE BALANCE LINES
CMT HEADERS
CMT DISCHARGE LINES
ACCUMULATOR STAND PIPE AND DISCHARGE LINES
IRWST DISCHARGE LINES
PASSIVE HEAT REMOVAL SYSTEM
IN-CONTAINMENT REFUELING WATER STORAGE TANK
AUTOMATIC DEPRESSURIZATION SYSTEM 1, 2, 3
AUTOMATIC DEPRESSURIZATION SYSTEM STAGE 4
PRESSURIZER
PRESSURIZER SURGE LINE
REDUCED LOOP SEALS

Transient	PLAUSIBLE PHENOMENA	ROSA Expectation
SGTR	PRHR Performance (NC included)	yes
	Effects on non-condensible nitrogen from accumulators (heat transfer, system pressure).	yes
	Mass & Energy transfer between primary and secondary.	yes
	Manometer effect between CMT and Pzr.	yes
	Recirculation from downcomer to CMT's.	yes
	Effect of PRHR performance on SG SRV's.	yes
	Local condensation in PBL and PRHR tubes	yes
	Interaction between Accumulator and CMT's.	yes
	Asymmetries and loop dependencies (which SG and its relation to the PRHR)	yes
SBLOCA	Check valve behavior in PBL and drain lines of CMT's	yes
	Draining characteristics of CMT's	yes
	Local condensation in PBL and PRHR tubes	yes
	Interaction between Accumulator and CMT's.	yes
	NC in the PRHR.	yes
	Asymmetric loop behavior	somewhat
	Thermal effects in the PRHR and CMT systems due to large temperature gradients.	yes
	Condensation in CMT's and PBL.	yes
	Manometer effect between CMT and Pzr.	yes
	Entrainment through Pzr surge line to ADS valves.	somewhat
	Effects on non-condensible nitrogen from accumulators (heat transfer, system pressure).	yes
	Temperature gradients in PRHR and CMT's.	yes
	Recirculation from downcomer to CMT's.	yes
	Locked rotor pump resistance effect.	yes
	Asymmetric behavior for pressure balance line breaks.	somewhat
	Integral system effects dependent on break location; asymetries, effects on CMT's, etc.	somewhat
MSLB	Additional asymmetry induced by PRHR cooling.	yes
	Boron transport to the core.	somewhat
	Boron dilution due to flow from downcomer to CMT's(recirculation path)	somewhat
	PTS due to temperature gradients and poor mixing.	somewhat
	NC in the PRHR	yes
	Manometer effect between CMT and Pzr.	yes
	Recirculation from downcomer to CMT's.	yes
	Local condensation in PBL and PRHR tubes	yes

INSTRUMENTATION

220 NEW CHANNELS

CMT X 2	ABSOLUTE PRESSURE	1
	DP	5
	FLUID TEMPERATURE	24
	WALL TEMPERATURE	13 PAIRS
PRZR PBL X 2	DP	2
	FLUID TEMPERATURE	3
	WALL TEMPERATURE	1
	FLOW	1
CL PBL X 2	ABSOLUTE PRESSURE	1
	DP	3
	FLUID TEMPERATURE	3
	WALL TEMPERATURE	1
	FLOW	1
	γ-DENSITOMETER	1
CMT HEADERS X 2	DP	1
	FLUID TEMPERATURE	1
CMT DISCHARGE X 2	DP	1
	FLUID TEMPERATURE	2
	FLOW	1
ACCUMULATOR AND DISCHARGE LINE X 2	ABSOLUTE PRESSURE	1 (AS INSTALLED)
	DP	1 (AS INSTALLED)
	FLUID TEMPERATURE	3 (AS INSTALLED)
	NITROGEN	1
	WALL TEMPERATURE	1
	FLOW	1 (AS INSTALLED)
IRWST DISCHARGE	DP	1
	FLUID TEMPERATURE	1
	FLOW	1

INSTRUMENTATION (CONT'D)

DVI LINE X 2	DP	1
	FLUID TEMPERATURE	1
	FLOW	1
PRHR	DP	5
	FLUID TEMPERATURE	11
	FLOW	1
	WALL TEMPERATURE	7
IRWST	DP	2
	FLUID TEMPERATURE	11
ADS 1, 2, 3	ABSOLUTE PRESSURE	1
	DP	2
	FLUID TEMPERATURE	2
	WALL TEMPERATURE	1
	Γ-DENSITOMETER	1
ADS 4 X 2	DP	3
	CATCH TANK	
	FLUID TEMPERATURE	2
PRESSURIZER	ABSOLUTE PRESSURE	2 (AS INSTALLED)
	DP	9
	FLUID TEMPERATURE	6
	WALL TEMPERATURE	6
PRZR SURGE LINE X 2	ABSOLUTE PRESSURE	1
	DP	2
	FLUID TEMPERATURE	1
	WALL TEMPERATURE	1
	Γ-DENSITOMETER	1
LOOP SEAL X 2	DP	2
	FLUID TEMPERATURE	1
	WALL TEMPERATURE	1
	FLOW	1 (AS INSTALLED)

FACILITY ACCEPTANCE

VERIFY THAT EQUIPMENT IS INSTALLED ACCORDING TO DRAWINGS

PRESSURIZE AND LEAK TEST ENTIRE SYSTEM

VERIFY OPERABILITY AND CALIBRATION OF INSTRUMENTATION

VERIFY OPERABILITY OF VALVES

VERIFY CONTROL LOGIC

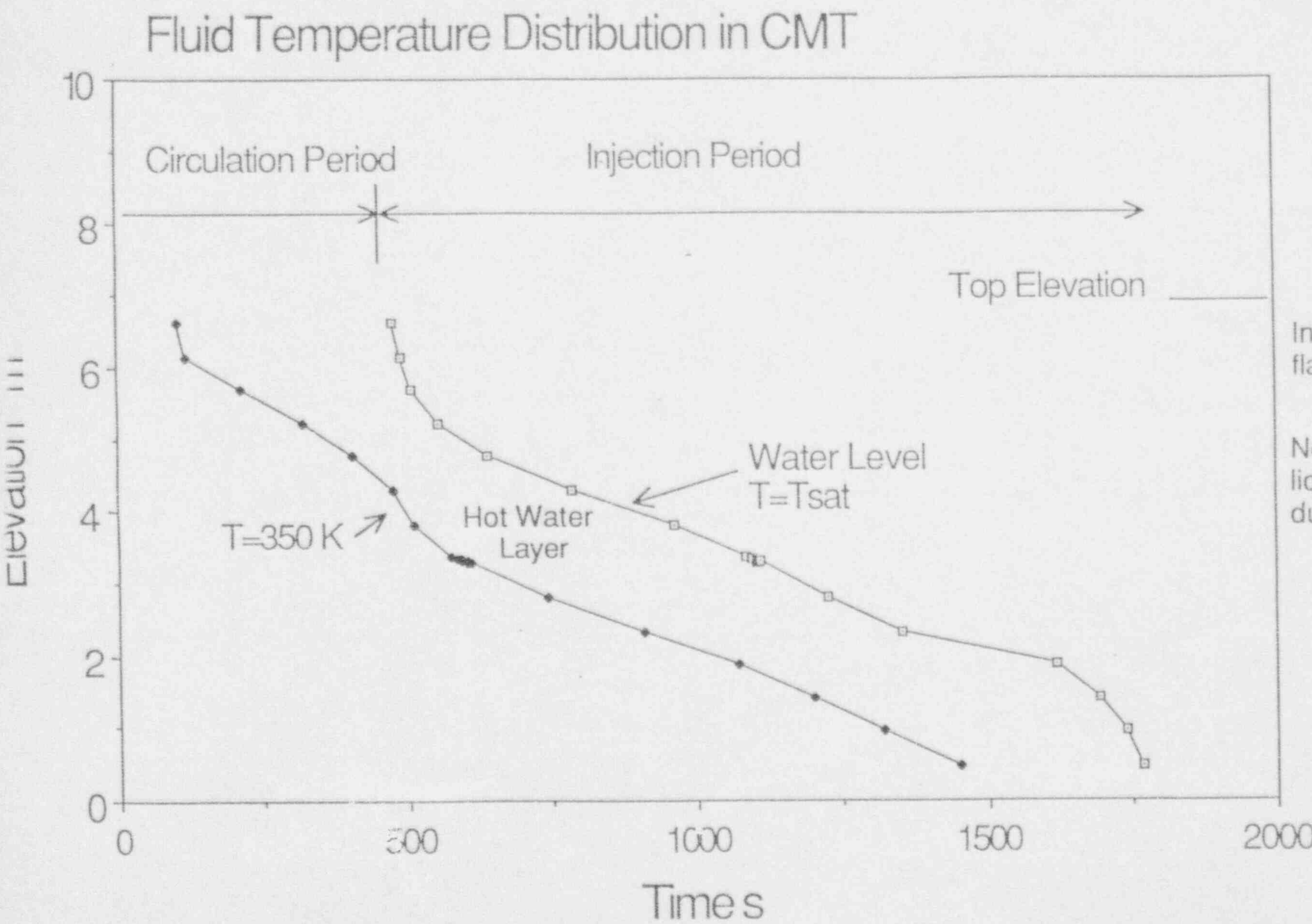
VOLUME VS ELEVATION OF EACH COMPONENT

FACILITY CHARACTERIZATION

1. CMT DRAIN/RECIRCULATION TESTS (VIA PRESSURIZER AND COLD LEG PRESSURE BALANCE LINES)
2. ACCUMULATOR BLOWDOWN
3. IRWST INJECTION (0 PSIG)
4. PRESSURIZER DRAIN
5. HEAT LOSS CHARACTERIZATION
6. PRHR TEST
7. ADS STAGE 1 BLOWDOWN (FROM 1000 PSI)
8. ADS STAGE 1+2 BLOWDOWN (FROM 700 PSI)
9. ADS STAGE 1+2+3 BLOWDOWN (FROM 400 PSI)
10. ADS SINGLE STAGE 4 BLOWDOWN (FROM 100 PSI)

TEST MATRIX

1. NO BREAK, INADVERTENT ADS STAGE 1 VALVE OPENING, SINGLE 4TH STAGE FAILURE
2. 1/2-INCH BREAK
3. 1-INCH COLD LEG BREAK
4. 1-INCH COLD LEG BREAK CVCS, NRHR SFW ON
5. 2-INCH COLD LEG BREAK
6. 4-INCH COLD LEG BREAK
7. DEGB DIRECT VESSEL INJECTION LINE
8. 2-INCH COLD LEG PRESSURE BALANCE LINE BREAK
9. DEGB COLD LEG PRESSURE BALANCE LINE BREAK
10. ONE SGTR
11. THREE SGTR
12. MAIN STEAM LINE BREAK



Indication of flashing at ~500 s

No measurable liquid accumulation due to condensation

CMT (accumulator tank) water level in LSTF Run SB-CL-27

INTEGRAL SBWR TEST FACILITY

DAVID E. BESSETTE

USNRC

ACRS T/H PHENOMENA SUBCOMMITTEE MEETING
MARCH 4-5, 1993

IDAHO FALLS, ID

OBJECTIVE

- TO OBTAIN CONFIRMATORY DATA FROM A SCALED, INTEGRAL TEST FACILITY THAT REPRODUCES MAJOR THERMAL-HYDRAULIC PHENOMENA OF INTEREST IN AN SBWR AT LOW PRESSURE

THE INTEGRAL SBWR FACILITY SHOULD HAVE

- VESSEL WITH ELECTRICALLY-HEATED CORE
- CONTAINMENT CONSISTING OF DRYWELL AND WETWELL
- GRAVITY-DRIVEN COOLING SYSTEM (GDCS)
- PASSIVE CONTAINMENT COOLING SYSTEM (PCCS)
- ISOLATION CONDENSER SYSTEM (ICS)
- VALVES AND PIPING
- INSTRUMENTATION AND CONTROLS
- RELEVANT NON-SAFETY SYSTEMS (FOR ASSESSING INTERACTIONS WITH SAFETY SYSTEMS

IMPORTANT ISSUES

1. VESSEL INVENTORY

   • GDCS PERFORMANCE EVALUATION

   - DRAINING CHARACTERISTICS OF GDCS POOLS

   - GDCS LINE BREAK OR VALVE FAILURE

   - AUTOMATIC DEPRESSURIZATION SYSTEM (ADS) VENTING CAPABILITY

   - ABILITY TO MAINTAIN SAFETY INJECTION UNDER SMALL PRESSURE DIFFERENCES

   - DECAY HEAT REMOVAL UNDER NATURAL CIRCULATION CONDITION AT LOW PRESSURES

2. CONTAINMENT INTEGRITY

   • PCCS PERFORMANCE EVALUATION

   - PERFORMANCE DEGRADATION DUE TO NON-CONDENSIBLES

   - PASSIVE VENTING OF NON-CONDENSIBLES

3. SYSTEM INTERACTIONS

   • INTERACTION BETWEEN GDCS AND NON-SAFETY CONTROL ROD DRIVE (CRD) WATER INJECTION INTO VESSEL

   • INTERACTION BETWEEN GDCS AND NON-SAFETY REACTOR WATER CLEANUP AND SHUTDOWN COOLING SYSTEM

   • INTERACTION BETWEEN PCCS AND NON-SAFETY DRYWELL SPRAY

TEST MATRIX

- SHOULD COVER A BROAD RANGE OF VESSEL AND CONTAINMENT CONDITIONS ANTICIPATED IN VARIOUS LOCAs AND TRANSIENTS
- RANGE OF TRANSIENTS AND BREAK

SCOPE

- TASK 1
  - IDENTIFY IMPORTANT PHENOMENA/PROCESSES FOR THE LOSS-OF-COOLANT ACCIDENTS (LOCAs) AND TRANSIENTS AS A BASIS FOR SCALING AND FACILITY DESIGN
  - DEVELOP SCALING RATIONALE
  - OUTLINE A TEST MATRIX
  - PROPOSE A PRELIMINARY FACILITY DESIGN FOR NRC TO REVIEW AND COMMENT
- TASK 2
  - COMPLETE A DETAILED FACILITY DESIGN INCLUDING INSTRUMENTATION LAYOUT
  - PREPARE A FINAL DESIGN REPORT FOR NRC TO REVIEW AND COMMENT
- TASK 3
  - PROCURE COMPONENTS AND CONSTRUCT THE FACILITY
- TASK 4
  - PERFORM FACILITY CHARACTERIZATION AND ACCEPTANCE TESTING WITH NRC STAFF
  - PREPARE A REPORT FOR NRC TO REVIEW AND COMMENT

SCOPE (CONT'D)

- TASK 5
  - PERFORM TESTS
  - REPORT RESULTS TO NRC
  - PROVIDE TEST CONDITIONS AND RESULTS TO INEL FOR CODE ASSESSMENT

STATUS

• SOLICITATION ISSUED	11/92
• CLOSING DATE	1/93
• SOURCE EVALUATION PANEL REVIEW	2/92
• CONTRACT AWARD	6/93
• COMPLETE DESIGN (TASKS 1, 2)	11/93
• COMPLETE CONSTRUCTION (TASK 3)	6/94
• COMPLETE STARTUP TEST (TASK 4)	8/94
• COMPLETE TEST SERIES (TASK 5)	2/95
• FSER ISSUED TO COMMISSION/ACRS	10/94
• FDA	1/95